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REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN NUTRITION *

E. W. CRAMPTON

Macdonald College

THE more one contemplates this rather innocuous sounding topic, the less straight-forward appears to be the pathway to the conclusion and final statement of the case. In attempting to organize my own thinking I have first broken the subject down into what seemed to be logical and perhaps obvious parts—dealing with each separately before attempting to draw any general picture.

Thus I shall present my material under the following headings:

I. Qualifications for admission to candidacy for the Ph.D.
II. Organized course work demanded of the graduate student.
III. The research project.
IV. Implications of the Ph.D. degree.
V. Requirements for the Ph.D. in nutrition.

Before going further, however, I wish to acknowledge the assistance of many members of our Society in furnishing information and opinions on this subject in response to a questionnaire. I also wish it understood that the principal object of this paper is to stimulate thought and discussion on a matter about which there is today no unanimity of opinion or procedure—which latter incidentally may be a strength rather than a weakness in the implications of the Ph.D. degree.

I. Qualifications for Admission to Candidacy for Ph.D. in Nutrition

Here at the outset one is faced with a definition of the field of nutrition. For our present purpose a dictionary definition is of little help. The subject matter making up the discipline of nutrition is diverse if we separate it into parts recognized academically.

Animal nutrition had its beginning in animal husbandry, in the so-called scientific feeding era when the scientific part was heavily supported by the feeders art in animal care. Here we may include the human subject as an animal and incidentally it may be surmised that if there had been applied to the feeding of the human as much

* Paper presented to the Teaching Session, American Society of Animal Production, November 1952.

art and science as was known and applied to the feeding of our pigs and chickens even in the early days of nutrition, some of our first dietary surveys might have shown different pictures. It was a long time indeed before the "chick starter" appeared as the now well-known, widely used, and in the eyes of some, the indispensable Pablum for babies.

Husbandry still forms the common ground through which the numerous science disciplines are linked into the nutrition montage. The nutrition worker who lacks the basic training in, and knowledge of the care and feeding of the animal itself, as well as a working knowledge of the appearance and behavior of the animal in normal health, is limited in his qualifications as a nutritionist irrespective of his other academic attainments.

The more important disciplines which have a direct bearing on the study of nutrition include chemistry, physiology, bacteriology, endocrinology, physics, mathematics, genetics, and cytology. These might be pictured as arranged "pie cut" fashion around the husbandry, indicating that of the subject matter in each, a part extends in application toward the common center, the nourishment of the animal.

If this is a reasonable picture of the situation, then one might depict an area enlarging the husbandry core to include wedges from each of these surrounding fields. Such an area might then be taken to define the subject matter of the present day discipline of nutrition.

This view of the scope of nutrition suggests to me that any acceptable candidate for advanced training in this field should have an acquaintance with all of these disciplines and a working knowledge of several of them. By a working knowledge I infer sufficient training to read the relevant literature with understanding and to be able to draw on the subject matter of the related disciplines so as to extend his knowledge largely by his own efforts.

This does not imply any hierarchal arrangement of the relevant disciplines. Indeed, a major or an honor standing in chemistry, or in physiology, or in bacteriology, would be equally as acceptable as specialization in animal husbandry or in household science, assuming in each case that the curriculum followed included adequate courses in the other related fields. The advantage of a thorough grounding in a major subject will be a function of the extent to which it has given the student some understanding of the nature of knowledge and the difficulties of arriving at valid knowledge. This implies a rather critical and thorough study of a limited field.

It is my impression that the B.Sc. curricula in animal husbandry and in household science at many institutions are unbalanced from the view of preparing students for advanced training in nutrition, being long on animal management and short on science, especially in the fields of chemistry and mathematics. On the other hand, cur-

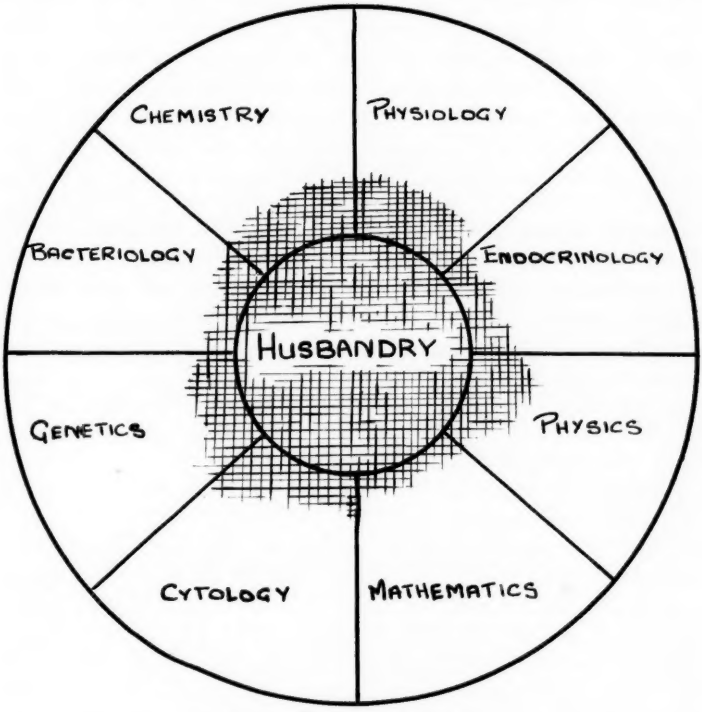

Figure 1. The field of nutrition.

ricula for undergraduate chemistry majors are likely to have omitted such courses as feeds and feeding, genetics, and physiology.

The consequence is that many Ph.D. candidates in nutrition must at the beginning patch up a badly shaped foundation, by devoting some of their post-graduate time to clearing off "prerequisites." Inasmuch as only a few of those seeking B.Sc. degrees are anticipating post-graduate study, the practical solution of a faulty undergraduate preparation may not be in drastic curriculum alteration excepting

perhaps by making available suitable courses and by encouragement to potential post-graduates toward the election of such courses in lieu of less applicable "choice" courses.

II. Organized Course Work at the Graduate Level

Ideally the object of post-graduate courses should be to advance the understanding of the student of the subject matter in fields already somewhat familiar from his undergraduate work as well as to increase his fund of information. In practice it appears that many courses "open" to post-graduate in nutrition are fundamentally undergraduate courses and are taken to acquaint the post-graduate with what to him is new subject matter. This situation, though not ideal, is probably inevitable, at least for some time to come, and arises because of the diversity of the facets in the field of nutrition.

By the same token it is futile to consider any standard curriculum of post-graduate courses. The animal husbandman may need physiological chemistry, while the chemist should have courses in the physiology of lactation and in feeds and feeding; and both may need extra training in statistics. Depending on the discipline from which the candidate has entered nutrition, the graduate course work will be different in both subject and extent in different cases. Obviously, each case must be dealt with individually and by those who will eventually be responsible for certifying that the requirements for the Ph.D. have been met.

There is, however, the matter of general policy with regard to the extent of course work at the strictly graduate level which should be required. There are evidently two schools of thought on this matter. In the view of some, the M.Sc. year has become a fifth year of undergraduate study, so extensive is the required course work. Little time is left for any research at this stage at those institutions favoring a heavy schedule of organized courses. Seemingly the objective in such cases must be an expansion of knowledge to the point where research becomes possible. If the year is merely devoted to increasing information and does not begin the process of inculcating the critical approach, then its value as training for the future investigator may be questioned.

In any case such a program might result in a situation in which the first step toward the Ph.D. (i.e. the M.Sc. year) is passed without adequate test as to whether or not the candidate has the aptitude and ability to do research. Many institutions feel that one

of the objects of Master's training is to establish whether a student has the qualities to make a research worker. If this objective is to be attained under a scheme requiring a heavy course schedule there must be a lengthening of the M.Sc. period, probably to two years instead of a minimum of one; or alternately the candidate asked to take a preliminary year of qualifying course work. This latter might, in fact, be an honor year of undergraduate work.

The regular requirement of a heavy schedule of prescribed graduate courses is quite a different matter to the election by the student of specific courses for the purpose of supporting some field in which he wishes to give special attention. Such courses may often justifiably be classed as cognate to the research and taken without examination or measured credit. They may well be the preferred method of facilitating some particular phase of the research. For example, a course in some bacteriological technique might be of immediate assistance in a nutrition research related to the role of antibiotics in hog feeding.

The decision as to which general plan of training is to be preferred can hardly be made here. It seems evident, however, that candidates who are admitted to post-graduate status and who must still pass any large number of prescribed courses must either spend longer in completing the Ph.D. requirements or else be granted the degree with less actual research training and experience than the Ph.D. is commonly expected to imply. Adequacy of the undergraduate curriculum will, of course, be a factor, but the policy of the institute with respect to the post-graduate curriculum will be the major consideration.

I am unaware of any trend in this matter or of any tendency for institutions to alter their views from those already established. Perhaps some of the trend toward a five year course for the B.Sc. may be in recognition of the post-graduate course problem. It may be of interest to note that several Canadian universities now demand five years for the B.Sc. in Agriculture, due to the extent of the subject matter which must be covered for acceptable professional standing in any special branch of Agriculture such as agronomy, animal husbandry, agricultural chemistry, etc.

III. The Research Project

Granting the questions of prerequisites and of curricula are important and can justify review and discussion, it is my belief that the

more difficult and perhaps the more significant problem relates to the research training. Completion of the requirements for a Ph.D. almost without exception, calls on paper for the presentation of a thesis based on original research. Consequently, someone or some group must approve a research project, define its scope, and ultimately judge whether or not it acceptably represents the requirement of independent research.

The underlying problem here again stems from the nature of what we define as the field of nutrition. Someone has expressed the matter in the statement that "we no longer can hunt alone." Worthwhile research in nutrition today is team play from start to finish. Thus it has become difficult to define a project which can be carried through as independent research by an individual, well-qualified researcher—let alone a beginner.

Because of this problem, I asked on the questionnaire: "To what extent is the research original?" The replies were enlightening. An example or two will suffice to indicate the picture.

> "Every effort is made to encourage and test ability to do original and independent research. . . ."
>
> "The student is a technical assistant. It is a rare student that has the background and maturity to plan, execute and interpret a project."
>
> "We expect them to contribute materially. . . ."
>
> ". . . the graduate thesis is so much a part of a team project . . . that the candidate does not have the opportunity to demonstrate his capacity for independent research."

I believe these make it evident that in practice the newly graduated Ph.D. in nutrition has ordinarily done but little independent research. He has rather been a junior member of a research group, and has usually acted in the capacity of technical assistant in carrying out a project which was planned primarily by others, guided through its progress by others, and finally interpreted as to basic conclusions by others. Undoubtedly the student has been in on the discussion and may have proposed ideas which have been used, but it may frequently be questionable whether he has been the real initiator of much of the research.

That this problem is real and recognized as such is indicated by the reply of one who said relative to this part of the questionnaire,

"I think your questionnaire hits on one of the limitations of graduate work in many institutions."

The matter of thesis then arises. Unfortunately, publication of so-called original research is often a major part of the qualifications scrutinized by a prospective employer. Later this may be taken as justification for promotion, or for election to Societies, or for some award. Many of the papers presented at our own sessions are essentially the presentation and defense of the Ph.D. theses of the speakers. To what extent can such theses be counted as original as to the research they represent? Can credit for originality in such research be justly claimed by any single member of the team of co-workers?

One who replied to this part of the questionnaire said: ". . . he (the student) is the quarterback of the team." While this may be true for each "play," the captain plans the strategy—often subject to the restrictions set by the coach who, in our case, may be the holder of the purse strings.

It is true that to a large degree the thesis, as presented, is the work of the candidate, and as such reveals his ability to organize, to present, and to appraise critically the pertinent literature on the subject and the research findings in question. This is, it seems to me, the major value of the usual Ph.D. thesis in nutrition as a part of the set requirements for the degree.

When the matter is looked at in the light of realistic possibility, and in many cases of current practice, the final year or, in some cases, two years of the Ph.D. period might better be treated as an apprenticeship in research rather than as time to be spent in carrying out independent research. It is in no way belittling to count research as a "trade," the "tricks" of which are best learned by serving an apprenticeship under the direction of those already qualified. And the more far-flung the subject matter to be covered, the more applicable the apprenticeship scheme of learning.

IV. Implications of the Ph.D. Degree

My own "sheepskin" has on it the following: "having performed the studies . . . we confer . . . the degree of Doctor of Philosophy with the Rights, Privileges and Honours there unto appertaining."

The implications of the Ph.D. are suggested in the words "Rights and Privileges." The term Doctor designates one who is skilled or

learned in some branch of knowledge—one who is entitled to express an authoritative opinion. The subject matter is philosophy, which originally comprehended the whole range of human interests. Scholastically, philosophy is defined as the knowledge of things through their highest causes. And so the relation of philosophy to research.

Thus the Doctor of Philosophy in nutrition is one entitled to speak with authority on matters pertaining to nutrition since he is presumed to have knowledge of the causes underlying the problems in this field.

I find nothing in the award which implies independent experimental research as the source of this knowledge. It is a degree which is awarded following completion of a prescribed schedule of study and training, a part of which has been aimed at learning something of the ways and means of experimental research. It is true that according to usual demands the research must have turned up something which can be counted as a contribution to knowledge, but this requirement in practice seems to be rather easily satisfied.

For many and various reasons, not the least of which is cost, projects in nutrition with which Ph.D. candidates can be associated at many institutions are likely to be a part of a Department's official research program. This again makes it necessary that the plan of the project, its guidance, and the ultimate interpretation of results be in the hands of senior staff. To arrange for special projects outside the Department's regular program which would be adequate for the training of Ph.D. candidates would be out of the question with many institutions. One would hesitate to believe that it follows that Departmental projects are not suitable as training for prospective research workers, merely because they were not designed by or especially for the apprentice.

The matter of cost was raised in the questionnaire, and from the replies it is evident that most Ph.D. candidates are being heavily subsidized from funds allocated to the research project. Their scholarships represent the cost to the project of technical assistance needed to carry on the research. Post Doctorate Fellowships, on the other hand, imply salaries to persons who are qualified to conduct or guide research either on their own or as an associate on a team.

Thus it appears to me that one should be entitled to assume that a newly graduated Doctor of Philosophy in nutrition has a working knowledge of the subject matter making up this discipline and has been associated in the capacity of technical assistant with one or more research projects of a scope comparable to those forming the

basis of papers acceptable for publication in recognized scientific journals. It should be a kind of certificate that the man has been judged capable of working on research either on his own or as a live member of a research team. On the other hand, one should not expect that this graduate has necessarily already done any important independent experimental research.

V. Requirements for the Ph.D. in Nutrition

To this point I have examined briefly some aspects of the problem of the Ph.D. in Nutrition. It is now necessary to crystallize the matter by making a specific statement of requirements. To this end I offer as a basis for discussion the following—presented in a form comparable to that found in University Announcements.

To qualify for admission to post-graduate training leading to the degree of Doctor of Philosophy in Nutrition the applicant must hold a Bachelor of Science degree, and have taken honors or Specialist standing in one of the following subjects: Animal Husbandry, Biochemistry, Bacteriology, or Physiology; and have completed major courses in the other three and in Statistics. Candidates having these qualifications may be admitted to post-graduate status.

Requirements include a minimum period of residence of three years, the completion of such courses as are judged necessary, and submission of a thesis based on experimental research with which the candidate has been associated. During the first year of post-graduate study, such courses in nutrition, chemistry, endocrinology, etc., as previous training may indicate are desirable, will be completed by examination. If more than three such courses are deemed necessary, the additional courses must be delayed to the second year and the minimum time to the degree extended by one year.

After the completion of required courses, the candidate will begin his research training which normally will involve associating himself with a Departmental research project as a technical assistant. This phase of the training will extend over a minimum period of two years during which time supporting courses elected by the student may be audited and any outstanding language requirements met.

At its completion, the candidate will prepare a thesis based on the results of the research with which he has been associated, and including a comprehensive and critical review of the relevant literature. This must represent his own work insofar as its organization and presentation are concerned; and its acceptability as a thesis will be

based more on these considerations than on the nature of the experimental findings which the research may have yielded.

I cannot bring myself to conclude this discourse without first making clear that though the final statements might appear to suggest the desirability of standardization in the matter of Ph.D. requirements. such is not the intent. There may be justification for some similarity with respect to starting points and minimum objective, but because there is a uniform seed bed it does not follow that but one kind of plant can be grown in the garden, or but one plan of cultivation used. You may recall a statement in the opening paragraphs of this paper to the effect that the lack of unanimity of opinion or procedure relative to the Ph.D. requirements was a strength rather than a weakness in the implications of the degree. A philosopher friend pencilled in the margin of a copy of this manuscript which he examined, the following comment:

> "Cultural uniformity marks the first phase of the death of the culture, even though the uniformity may in itself be a culmination."

We would do well to heed this warning in any discussion of the problem of Ph.D. training.

WHAT SHOULD BE THE REQUIREMENTS FOR THE PH.D. DEGREE IN ANIMAL BREEDING? [1]

W. A. CRAFT

Director, Regional Swine Breeding Laboratory, Ames, Iowa

I SHALL attempt to express only my own views regarding the question posed by the title given me. The views I shall express are the crystallization of my own experience, limited as it is, working in the field, watching young men, trying to lend encouragement to them, and observing their difficulties.

The Ph.D. degree training is an attempt to train the student to know a great deal about one subject, but also to know enough about basic sciences to fit specialties into the whole array of modern knowledge and social action. Thus recipients of the Ph.D. degree in animal breeding are not to be animal breeders only, but they are to be also, all-around active citizens.

A system of designated courses of study has proved to be useful to both teachers and students. That is the means through which students and teachers meet and work. These systems or curricula for various degrees are prescribed by colleges and universities. The requirements are determined in part by teachers who offer the courses. Subject matter of the courses usually is indicated by a brief statement in the catalogues. But in the end the teacher largely determines the subject matter in individual courses. Accordingly the importance of the teacher is emphasized again and again.

It should be recognized that students capable of doing graduate study are not all endowed with the same aptitudes. Those who possess imagination and analytical skill to a high degree, should be guided with emphasis on advanced courses which offer most in developing their particular talents and they should be encouraged to enter the research field. On the other hand there are students, though lacking in some of the qualities desired in research men, who can serve well in one or the other fields of animal husbandry when trained in the basic courses. All of these students should have enough training in the basic sciences, including statistics, to enable them to understand research methods and to interpret research reports.

Then what courses should be required for the Ph.D. degree in

[1] Talk presented at the Teaching Section at the Annual Meeting of the American Society of Animal Production, November, 1952.

animal breeding? Some reasonable standard of academic background is necessary. Usually graduation with a major in one of the divisions of animal industry is required. I believe this is good. But latitude should be given major professors in that regard so that they may exercise judgment in accepting promising students who may not have such an academic background. There are occasionally such students wanting to enter the field. Some of these are needed indeed, and should not be barred or hindered by the necessity of meticulously following a prescribed background.

Graduate courses should include: biochemistry, comparative anatomy, cytology, embryology, endocrinology, ecology, physiology, nutrition, genetics, statistics and animal breeding. Statistics is an exceedingly useful tool in the field of animal breeding. Candidates for the Ph.D. degree need not all be statisticians, but enough statistics should be mastered to enable the student to use at least the elementary procedures, and to recognize circumstances which pose the need for advanced statistical techniques. It would be presumptuous for me to recommend the amount of credit in the various courses. That should be determined largely by the major professor in consideration of the background and specific interests of the student, and the credit hours should not necessarily be the same for all students. Subject matter of the courses selected should provide a broad but comprehensive basic training. Students in animal breeding should be familiar with the problems, techniques and results in the field of plant breeding.

Developments in science and technology have placed the various divisions of agricultural science on a professional basis. The field requires professionally trained teachers, research men, extension men, and animal breeders. Therefore, the graduate training of men in animal breeding should prepare them as professional men.

There are some who believe that undergraduate training in animal husbandry is not, at the present time, adequate in respect to livestock management.

Management has been recognized as being of utmost importance to stockmen since early times, and this aspect of livestock production may become increasingly important to both stockmen and research workers in the next decade or so. This point was called to the attention of the teaching section of the Society in 1951 by the collaborators of the Regional Swine Breeding Laboratory. Curricula and subject matter of individual courses in the undergraduate level should be strengthened whenever possible with respect to livestock management.

Men are needed for research, teaching, extension specialists and animal breeders trained adequately both in the basic sciences and management aspects.

It is probably pedantic to point out to this group that research is basic to teaching in the field of animal production; that without research in fields such as ours teaching becomes stale and inadequate; and that we must meet the changes imposed by developments in our own and related fields. But I desire to emphasize that research should not be permitted to lag, either for lack of trained personnel or for lack of funds.

Finally, training for the Ph.D. degree in animal breeding should increase the students over-all perspective, sharpen his ability to recognize problems, improve his skill in evaluating problems and working toward solutions of them.

EFFECTS OF VARIOUS LEVELS OF AUREOMYCIN IN FATTENING LAMBS[1]

J. H. Bridges, J. C. Miller, W. G. Kammlade, Jr. and H. O. Kunkel[2]

Texas A & M College System[3]

SINCE the original observations (Carpenter, 1950; Jukes *et al.*, 1950) in which aureomycin was shown to stimulate growth rate in swine and poultry when added to a complete diet, the value of antibiotics in the rations of monogastric farm animals has become well established.

Similar beneficial results have been obtained in dairy calves. Bartley *et al.* (1950) and Loosli *et al.* (1951) observed that aureomycin feeding increased the average daily gains of calves and reduced the incidence and severity of scours. Rusoff (1951) reported an increased rate of gain and a more thrifty appearance in calves receiving 90–180 mg. daily of the antibiotic.

Colby *et al.* (1950), however, obtained a decline in growth rate of lambs fed 100 mg. daily of either aureomycin, penicillin or streptomycin. Similar results were observed by Bell *et al.* (1950) in beef steers. In contrast, Warner (1952) has cited data that as much as 700 mg. aureomycin in a feeding supplement was fed in the grain portion of the dairy cow ration for several days without harmful effects. Also, Neuman *et al.* (1951) demonstrated that aureomycin at a level of 2 mg. per lb. feed caused no unfavorable disturbances in yearling beef heifers, but at the same time no improvement was noted.

Wasserman *et al.* (1952) reported that certain antibiotics stimulated cellulose digestion by rumen microorganisms *in vitro*. Jordan (1952) fed aureomycin at levels of 7 to 14 mg. daily to lambs over a period of 100 days without detriment and suggested such beneficial effects as improved gains in unthrifty lambs, greater ease in getting lambs on full feed, and partial protection from enterotoxemia.

From these considerations it appeared that further studies of the effect of feeding various levels of aureomycin on growth rate, feed efficiency and general thriftiness of feeder lambs would be desirable.

[1] Supported in part by a grant-in-aid from the Lederle Laboratories Division, American Cyanamid Corporation, Pearl River, New York, to the Texas Agricultural Experiment Station.

[2] The authors are indebted to S. L. Reynolds for assistance in this study.

[3] Departments of Biochemistry and Nutrition and Animal Husbandry, College Station, Texas.

In addition information regarding the influence of aureomycin in rations containing various proportions of concentrates and roughage seemed pertinent.

Experimental Procedure

Three feeding trials were used to evaluate aureomycin in lamb fattening rations. The first of these was conducted in the fall of 1952. In this trial, 57 Rambouillet×Corriedale wether lambs were divided into 6 lots. These were hand fed a ground ration containing 42.5 percent milo, 7.5 percent cottonseed meal, 49 percent alfalfa hay, 0.5 percent steamed bone meal, and 0.5 percent salt for 84 days. Then the milo was increased to 52.5 percent and the hay reduced to 39 percent during the last 28-day period. Where fed, aureomycin was furnished by Lederle Aurofac 2A (3.6 gm. aureomycin per lb.) in quantities to supply 1.1, 2.2, 3.2 and 4.3 mg. aureomycin per pound of feed. One lot received 2.2 mg. crystalline aureomycin hydrochloride in order to compare the feed grade material with the pure drug.

Rambouillet×Panama ewe and wether lambs were used in experiments 2 and 3 which were conducted in the spring of 1953. In experiment 2, two lots of lambs were started on a feed of 50 percent ground milo and 50 percent ground alfalfa hay fed *ad libitum* after 10 days for 28 days. The rations were then changed to 60 percent milo and 40 percent hay for the duration of the 84-day test. One lot received 5 mg. of aureomycin (supplied by Aurofac 2A) per pound of feed. In experiment 3, four groups of lambs were fed. Levels of 1.25, 5.0, and 15.0 mg. aureomycin per pound of feed were compared to a control. The lambs were started on feed using a 1:3 mixture of concentrates (ground milo plus aureomycin where fed) and ground alfalfa hay. At biweekly intervals the proportions were changed to 1:2 and 1:1. The 1:1 proportion was maintained throughout the last 56 days of the trial.

In each trial the lambs were allotted according to weight, condition and sex. They were drenched with phenothiazine prior to being placed on experiment. During the trial they were hand fed twice daily and weighed at 28 day intervals.

Results and Discussion

The results of the three experiments are shown in table 1. In all cases, the gains of the aureomycin fed lambs were equal to or slightly above the control groups regardless of the proportions of roughage

to concentrates in the ration. Differences in gain were not statistically significant, however, even though there was as much as .06 pound increase in average daily gain in some of the aureomycin fed lots. This improvement may be real, but larger numbers will be required to show a statistical significance.

In view of the effects reported by Colby *et al.* (1950) it is significant that aureomycin showed little or no detrimental effect on gains at the levels fed in these experiments. At the beginning of the experiments the lambs receiving aureomycin scoured appreciably and the feed consumption was decreased to 60 percent as much feed as the control animals in the test when 15 mg. aureomycin was fed per pound of feed, but after about 2–3 weeks scouring decreased and feed consumption improved. Jordan (1952), reported that 14.4 mg. per lamb daily reduced the rate of gain and feed efficiency under his experimental conditions. However, the lambs in these tests which received the 5.0 mg. of aureomycin per pound of total feed consumed as much as 16 mg. of aureomycin per day, and the group receiving 15.0 mg. of aureomycin per pound of total feed consumed 48 mg. of aureomycin per lamb daily throughout a considerable portion of the experimental period.

Perhaps of greatest significance is the observation that the low levels of aureomycin in these tests apparently resulted in improvement of feed efficiency. In experiment 1 the groups receiving 2.2–4.3 mg. of aureomycin per pound of feed required 5 to 12 percent less feed per pound of gain than the control animals. In experiment 2 in the lot fed the aureomycin this difference was 5.5 percent. In experiment 3, the group fed the 5.0 mg. level of aureomycin was about 10 percent more efficient in feed utilization, while the lots fed 1.25 and 15.0 mg. per pound of feed were similar to the control animals in feed efficiency. In all 3 experiments the addition of 2.2–5.0 mg. of aureomycin per pound of feed resulted in a more efficient use of feed. Improvement of feed efficiency was not evident using 1.25 mg. aureomycin per pound of feed in experiment 3 and it appeared that the 15.0 mg. per pound was too high to result in improvement.

No differences were noted in the effects produced by crystalline aureomycin and aureomycin as supplied by Aurofac 2A when fed at comparable levels. At the 5 mg. level, aureomycin gave most benefit when the lambs were started on feed using a low concentrate ration (table 1).

Preliminary carcass studies though quite inconclusive, have suggested

TABLE 1. EFFECT OF VARIOUS LEVELS OF AUREOMYCIN IN THE DIET OF FATTENING LAMBS

Experiment	Days on Test	Aureomycin Level	No. of Lambs	Death Loss	Av. Initial Weight	Av. Daily Gain	Av. Daily Feed Consumption	Feed Efficiency
		mg./lb. of feed			lb.	lb.	lb./lamb	lb. feed/100 lb. gain
Experiment I								
Started with high concentrate diet[1]	112	0	10	2[5]	56.0	0.34±.015	2.66	778
		1.1	10	1[6]	55.8	0.39±.014	2.86	733
		2.2	8	0	55.5	0.36±.016	2.60	716
		2.2[4]	10	0	55.1	0.37±.019	2.70	738
		3.2	9	0	56.5	0.39±.019	2.68	687
		4.3	10	0	54.8	0.35±.016	2.53	716
Experiment II								
Started with high concentrate diet[2]	84	0	18	0	62.3	0.35±.031	2.79	808
		5.0	17	1[7]	64.2	0.38±.005	2.88	764
Experiment III								
Started with low concentrate diet[3]	84	0	15	0	61.0	0.39±.027	3.12	793
		1.25	16	1[7]	59.8	0.42±.029	3.23	775
		5.0	16	0	62.2	0.45±.027	3.20	713
		15.0	15	0	61.6	0.40±.031	3.15	785

[1] Milo—42.5%, cottonseed meal—7.5%, alfalfa hay—49%, bone meal—0.5%, and salt—0.5%, first 84 days; milo 52.5%, alfalfa—39% final 28 days.
[2] Milo—50%, alfalfa—50%, first 28 days; milo 60%, alfalfa—40%, final 56 days.
[3] Milo—25%, alfalfa hay—75%, first 14 days; milo—33%, alfalfa hay—67%, second 14 days; milo—50%, alfalfa hay—50% remainder of test.
[4] Crystalline aureomycin hydrochloride.
[5] Death due to enterotoxemia.
[6] Death due to accident.
[7] Death due to peritonitis.

a slight increase in dressing percentage and carcass grade as a result of aureomycin feeding.

Death losses in the three experiments were relatively small, however, in the control lot of experiment 1 two lambs died. Post mortem examination showed enterotoxemia as the cause of death. Enterotoxemia was not observed in any other group although many of the lambs were fed heavily on concentrates in the early part of the experimental period.

The results of these trials indicate no deleterious effects on gain when aureomycin is included in the diets of feeder lambs at levels up to 5.0 mg. per pound of total feed. If the suggestion by Jordan (1952) that aureomycin will reduce overeating disease or enterotoxemia proves to be true and the finding of improved feed efficiency continues to be consistent, then low levels of aureomycin and perhaps other antibiotics may be of value in the rations of fattening lambs.

Summary

Aureomycin as a feeding supplement was fed to lambs at levels of 1.1 to 15.0 mg. per pound of feed in rations composed of milo and alfalfa hay; and milo, cottonseed meal and alfalfa hay.

Increases in rate of gain resulting from feeding the aureomycin were relatively small and were not significant statistically. An apparent improvement in feed efficiency was evident when aureomycin was fed at levels of 2.2 to 5.0 mg. per pound of total feed.

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THE EFFECT OF SHEARING ON THE REACTION OF LAMBS TO HIGH ENVIRONMENTAL TEMPERATURE

J. L. Fletcher and George R. Reid [1]

Mississippi Agricultural Experiment Station [2]

ALTHOUGH climatic factors primarily affect animals indirectly through their effect on quantity and quality of plant food products certain of these factors have a direct effect on physiological functions of the body. As pointed out by Lee and Phillips (1948) animals in tropical and subtropical climates may be severely burdened by the necessity of eliminating excess heat from the body. Ritzman and Benedict (1931) showed that the wool covering of the sheep was important in retarding the loss of heat from the body surface. An increased rate of respiration and an increased body temperature were noted by Miller and Monge (1946) and Robinson and Lee (1947) as responses of sheep to high environmental temperature.

Several workers have studied the effect of shearing on the rate and efficiency of gain of lambs. Dyer (1950) reported that shearing did not improve the gains of grazing lambs during the summer and fall. Harper (1938) and Keith and Henning (1938) secured slightly more rapid and efficient gains in the feed lot from shorn lambs than from wooled lambs. Decidedly superior gains by shorn lambs grazing summer pasture in Mississippi were reported by Leveck (1948). It was stated that shorn lambs gained 0.31 pounds per day as compared to 0.12 pounds per day for unshorn lambs.

The present investigation was prompted in large part by the striking results from shearing secured by Leveck (1948). The objective was to determine the effect of shearing on body temperature and respiration rate reaction of lambs to the high summer temperature often encountered in Mississippi.

Experimental

Southdown-sired grade lambs ranging in weight from 42 to 53 pounds were used in the experiment. The lambs were allotted at random to three groups of three lambs each. Group 1 served as the control and these lambs were not shorn. In group 2 a strip about

[1] Present Address: Wilson & Co., Oklahoma City, Oklahoma.

[2] Dr. W. J. Drapala, Statistician, Mississippi Experiment Station kindly assisted with statistical analysis.

four inches wide along the back of the lambs from the head to the dock was clipped. The lambs in group 3 were completely shorn. All three groups of lambs were housed and fed together. They were housed in a shed open to the south and in which water was available at all times.

Body temperature and respiration rate determinations were made on ten test days. On each test day data were secured at 10:30 A.M. and at 3:00 P.M. Body temperature was determined rectally by use of a veterinary thermometer and respiration rate was determined by counting flank movements. Care was taken to insure as little excitement of the lambs as possible in the process of securing data. The atmospheric temperature in the shed at a height of 18 inches above ground was determined both in the morning and in the afternoon. The test days chosen were between July 2 and July 13.

TABLE 1. THE EFFECT OF SHEARING ON THE BODY TEMPERATURE AND RESPIRATION RATE OF LAMBS

		Body Temperature (degrees F.)			Respiration Rate (times per minute)		
Group	Treatment	AM	PM	Ave.	AM	PM	Ave.
1	Control	105.2	105.6	105.4	154	158	156
2	Back clip	105.3	105.4	105.4	141	153	147
3	Shorn	104.5	104.8	104.6*	100	126	113*
Average		105.0	105.2	.....	132	146	...

* Significant in comparison with the control: $P<0.01$.

One lamb in group 2 went off feed on the seventh day and was considered abnormal. All data taken on this lamb were discarded.

Results and Discussion

The results are summarized in table 1. The atmospheric temperature at the time of the morning determinations averaged 90° F. and ranged from 82° F. to 96° F. The afternoon temperatures ranged from 85° F. to 102° F. and the average was 96° F. The afternoon temperature was higher than the morning temperature on the same day in every instance.

The average body temperatures of all the groups of lambs at both times of the day were above the normal temperature of 102.3° F. cited by Dukes (1943). The average body temperature of the shorn lambs was 0.8° F. lower than that of the control lambs in group 1.

Lambs clipped only on the back had an average body temperature of 105.3° F. which was only 0.1° F. lower than that of the controls. These data were analyzed by the method of unweighted means as described by Snedecor (1946). The differences in mean temperature for the groups were highly significant. Additional analysis showed that only the shorn lambs differed significantly from the controls. Thus it appeared that clipping a strip along the back was of no value in controlling the rise in body temperature.

The respiration rate data in table 1 show a response similar to that for body temperature. There was a statistically significant difference between the treatments. Again only group 3 differed significantly from the controls. The lower rate of respiration indicates that the shorn lambs were expending less respiratory effort in an attempt to maintain a normal body temperature. The slight increase in respiration rate in the control lambs between morning and afternoon determinations suggests that a maximum rate of respiration might have been approached by these lambs.

The significant reduction in the rate of respiration and in body temperature which resulted from shearing indicates a possible contributing cause to the superior gains by shorn lambs at this same location reported by Leveck (1948). In view of the variation in response for sheep of different breeds as reported by Miller and Monge (1946) it must be recognized that lambs of other breeding than that used might have given different results.

Summary

Grade Southdown lambs were used in an experiment to determine the effect of shearing on the body temperature and respiration rate of lambs under summer conditions in Mississippi. Three groups of three lambs were used. One group was shorn while another was clipped only along the back. The third group was allowed to remain in the fleece and served as a control. Body temperature and respiration rate determinations were made twice daily on ten days during the month of July. The average atmospheric temperature at the morning determination was 90° F. and in the afternoon it was 96° F. The shorn lambs were found to have a significantly lower body temperature and respiration rate than the other two groups. There was not a significant difference in the reaction of the lambs in the fleece and those shorn only along the back. The greater efficiency of control of the body temperature exhibited by the shorn lambs suggests at

least a partial explanation for the more satisfactory gains reported by certain workers.

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EFFECT OF STILBESTROL ON SUCKLING AND FATTENING LAMBS [1]

R. M. JORDAN [2, 3]

South Dakota Agricultural Experiment Station

THE effect of certain hormones on the growth rate, feed efficiency, and some physiological factors of cattle has been demonstrated by Dinnuson *et al.* (1950) and Andrews *et al.* (1950). These workers treated yearling heifers and steers with various levels of stilbestrol and obtained significant increases in rate of gain, feed efficiency and some increase in feed consumption. Andrews *et al.* (1949) reported on the effects of stilbestrol on feeder lambs. A significant increase in rate of gain and feed efficiency was obtained. However, this increase in growth rate was accompanied by a decrease in carcass grade. These findings were confirmed by Pope *et al.* (1950), Jordan (1950), and Jordan *et al.* (1951). Growth response of suckling lambs to stilbestrol treatment has not been consistent. Perry *et al.* (1951) reported a significant increase in rate of growth of 46-pound suckling lambs that had been treated with 12 mg. of stilbestrol. Most of this increase in growth rate was made during the first 28 days following treatment. Jordan and Dinnuson (1950) obtained no increase in growth rate of suckling lambs weighing approximately 25 pounds that had been treated with 12 mg. of stilbestrol. Clegg (1952) reported 100 percent greater nitrogen retention by steers treated with stilbestrol as compared to untreated steers. Whitehair *et al.* (1953) ascribed to stilbestrol treatment an 83 percent increase in nitrogen retention by lambs.

The purpose of these experiments was to obtain additional data on the effect of stilbestrol on growth rate of lambs at different ages, feed efficiency, nitrogen retention, carcass quality and yield, shrinkage following slaughter and shrinkage during cooking.

Procedure

Two trials were conducted with suckling lambs during 1950 and 1951. In the first trial lambs 2–2½ months of age were used while

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in the second trial lambs 3½ to 4 months of age were used as test animals. Approximately half of the lambs in each trial were treated with a subcutaneous implantation of 12 mg. of stilbestrol in the jaw. The lambs were allotted to treatments equally on the basis of their age, sex, and whether they were twin or single lambs. Creep feeding of the lambs was discontinued at the time they were turned on alfalfa-brome pasture. In the second trial treatment was made after the lambs were on pasture. Weights were taken periodically and observations made on type and condition of the lambs, and the development of their external sex organs and mammary glands.

Fifty-four high quality blackface Idaho feeder lambs were used as test animals during the fall of 1951 to study the effect of 12 mg. stilbestrol on rate of gain, feed efficiency, nitrogen retention, carcass grade and yield, carcass shrink following slaughter and cooking shrinkage. Twenty-seven lambs were treated with a 12 mg. pellet of stilbestrol implanted subcutaneously in the jaw. The lambs were full-fed for a period of 91 days a ration of shelled corn, alfalfa hay and soybean meal pellets and had access to minerals, salt, fresh water and shelter. Three lambs from each group were slaughtered at the college meat laboratory and data gathered on carcass shrinkage following slaughter, and cooking shrinkage.

Fifty days after treatment 6 lambs from each group were placed in metabolism crates. Methods and equipment used were the same as described by Briggs *et al.* (1949). The preliminary and collection periods were 14 and 10 days respectively. One lamb in the treated group died the second day of the preliminary period and data from one lamb in each group was discarded because of their failure to eat while in the metabolism crates. A ration of shelled corn and alfalfa hay was fed. The amount fed per lamb was determined by the amount consumed by the lamb that was eating the least.

Cooking shrinkage was determined on leg of lamb from two lambs from each group. All four of these lambs graded choice. The legs of lamb were placed on metal grids and the leg and metal grid placed in separate roasting pans and weighed. Cooking temperature was 75° C., as prescribed by Lowe (1949). Weights were taken of the individual legs, grid and pan upon removal from the oven. The difference in weight of the uncooked meat, metal grid and pan, and the weight of the cooked leg of lamb, grid and pan, accounted for the loss due to vapor. The drippings were poured into pyrex graduates and measured to the nearest milliliter and then allowed to stand

for fifteen minutes to allow the fat to rise and the meat fluid to settle. Measurements of these two fractions were made.

Shrinkage was obtained by weight difference of the warm carcass and chilled carcass 24, 48 and 72 hours following slaughter.

Results

Suckling Lambs

The results of the two trials are presented in table 1.

TABLE 1. EFFECT OF STILBESTROL ON GROWTH RATE OF SUCKLING LAMBS

Item	Experiment I		Experiment II	
	Lot I Control	Lot II Treated	Lot I Control	Lot II Treated
No. of lambs	12	12	21	25
Days fed	71	71	58	58
Av. initial wt., lbs.	38.7	43.5	48.5	47.1
Av. final wt., lbs.	74.8	79.9	72.2	72.4
Gain/lamb, lbs.	36.1	36.4	23.7	25.3
Av. daily gain	.509	.513	.409	.437

The average daily gain of the two groups of lambs in the first trial was virtually the same. (Control .509 *vs.* treated .513 pound per lamb daily.) In the second trial in which lambs with more age and size were used, the control lambs gained 0.409 as compared to 0.437 for the treated lambs. This difference was not statistically significant. These results are in agreement with an earlier trial at this station (Jordan and Dinnuson, 1950) and with results obtained at the Minnesota station (Jordan, 1951). Perry *et al.* (1951), reported a highly significant difference in growth rate between control lambs and stilbestrol treated lambs weighing about 46 pounds. The slightly greater gains made by the treated lambs in the second trial as compared to no increase between the two groups in the first trial suggests that age may be an important factor in regard to growth response to stilbestrol implants.

No difference in length of leg and body or condition was noted between the two groups of lambs in either trial. The effect of stilbestrol on the vulva and mammary glands of the ewe lambs and the testes and nipples of the ram lambs was discernible. This was particularly true in the second trial among older lambs. Normal

appearing milk could be expelled from all the ewe lambs and a majority of the ram lambs in the second trial. The testes of the ram lambs were decidedly smaller among the treated lambs than the control lambs. However, about 4 months post-treatment the testes appeared normal in all ram lambs but one. The testes of this ram gradually increased in size and appeared normal about 6 months after treatment. Breeding records on the treated ewe lambs and ram lambs indicated that fertility was not permanently impaired by treatment. All of the ewe lambs conceived when bred as yearlings and

TABLE 2. EFFECT OF STILBESTROL ON GROWTH RATE, FEED CONSUMPTION, FEED EFFICIENCY AND CARCASS GRADE OF FATTENING LAMBS

Item	Lot I Control	Lot II Treated
No. of lambs	27	27
Days fed	91	91
Av. initial wt., lbs.	64.4	63.9
Av. final wt., lbs.	101.2	108.8
Gain/lamb, lbs.	36.8	44.9
Av. daily gain	.405	.493*
Av. daily feed consumed:		
Grain	1.20	1.25
Hay	1.43	1.50
Protein	.20	.20
Feed per 100 lbs. gain:		
Grain	296.7	251.7
Hay	353.7	302.0
Protein	49.5	40.5
Carcass yield	48.8	47.6
Carcass grade:		
Prime	15	8
Choice	3	11

* Highly significant difference at the one percent level.

the ram lambs settled the ewes bred when used as 9 to 10 months old ram lambs.

Fattening Lambs

The results of treating high-quality feeder lambs with 12 mg. stilbestrol are shown in table 2.

Rate of gain was increased by stilbestrol treatment as the treated lambs gained about 0.09 pound faster per lamb daily. This difference was statistically significant. The difference in daily gain was not as great as reported by O'Mary *et al.* (1952) and Andrews *et al.* (1949).

This may be due to the fact that the feeding period was 91 days duration which is considerably longer than those workers have reported. While the lambs were full-fed, only slightly more feed was consumed by the treated groups (controls consumed 1.40 pounds concentrate, and 1.43 pounds hay as compared to 1.45 pounds concentrate and 1.50 pounds hay by the treated lambs). This slight increase in feed consumption is not sufficient to account for the difference in daily rate of gain between the two groups.

Feed efficiency was greater among the treated lambs as approximately 15 percent less concentrates and 15 percent less hay was required per 100 pounds of gain by the treated lambs than by the controls.

TABLE 3. EFFECT OF STILBESTROL ON SHRINKAGE IN COOLER

Item	Controls			Treated		
Lamb number	2243	2351	2390	2357	2254	2148
Live wt., lbs.	102.0	97.0	87.0	98.0	99.0	105.0
Warm carcass wt., lbs.	57.50	52.75	46.75	52.00	49.00	54.25
Carcass wt., 24 hrs., lbs.	56.25	51.50	45.75	50.00	47.50	51.75
Carcass wt., 48 hrs., lbs.	55.75	51.00	45.00	49.50	47.00	51.25
Carcass wt., 72 hrs., lbs.	55.50	50.75	44.75	49.00	46.50	50.75
Loss first 72 hrs. following slaughter	2.0	2.0	2.0	3.0	2.5	3.5

Carcass Data

Carcass data gathered from the two groups of lambs slaughtered at the packing plant showed that the carcasses from the control lambs graded considerably higher than the treated lambs. The carcasses of the control lambs yielded 48.8 percent as compared to 47.6 percent by the treated lambs. These findings are in agreement with previous work reported by this station. The carcasses from the treated group were characterized by being longer and more mature appearing and lacking in external and internal fat. In addition they lacked firmness of flank, were more prominent in the hips and felt more soft and watery than the control carcasses.

Shrinkage Following Slaughter and Cooking

The data on carcass shrinkage following slaughter and shrinkage during cooking is presented in tables 3 and 4. The greatest shrinkage during the holding period of 72 hours at 34° F. occurred among the

treated lambs and the largest amount occurred during the first 24 hours. During the first 24-hour period the treated lambs shrank an average of 2 pounds. During the same period the control lambs shrank 1¼ pounds. From the time of slaughter until 72 hours later, the average carcass shrink of the control lambs was 2 pounds as compared to an average 3 pounds shrink for the treated lambs. Additional data on shrinkage following slaughter confirm these findings (Jordan, 1953).

The effect of any treatment on shrinkage during cooking is of vital importance. The results from roasting leg of lamb from two treated and two control lambs suggest that the total shrinkage during cooking is not greatly affected by treatment. Slightly less water

TABLE 4. EFFECT OF STILBESTROL ON COOKING SHRINKAGE

Item	Control	Treated
Number of lambs	2	2
Percent lost as water vapor	15.90	13.70
Percent lost as drippings	17.90	16.70
Percent water in drippings	49.60	60.75
Percent fat in drippings	50.40	39.25

vapor was lost during cooking from the legs of lamb from treated lambs (average of controls 15.9% *vs.* treated 13.7%). There was only a slight difference in total drip between the two groups. The two legs from the treated lambs lost an average of 16.7 percent total drippings while the two legs from the untreated lambs lost an average of 17.9 percent. However, the amount of fat and meat juice in the drippings differed greatly between the two groups. Of the total amount of drippings, fat and meat juices, 50.4 percent was fat in the control lambs as compared to an average of only 39.3 percent fat in the treated group. This indicates that the treated lambs had less fat and more moisture in the legs of lamb than was true in the case of the control lambs.

Metabolism Trial

The effect on digestibility and nitrogen retention of 12 mg. of stilbestrol implanted subcutaneously in fattening lambs 50 days prior to a nitrogen balance study is shown in table 5. The quality of the alfalfa was excellent and contained 18.48 percent protein. The digestion coefficients of the various nutrients by the lambs within a group were considered to be in close agreement. These data afford good

evidence that treatment with stilbestrol has no effect on digestibility of any of the feed nutrients.

While there was considerable variation in the amount of urine voided between lambs within a group the average amount of urine voided by the stilbestrol treated lambs was less than the control lambs. The amount of nitrogen per milliliter was about equal between the two groups with slightly more nitrogen excreted per milliliter by the treated group. Therefore any difference in nitrogen retention

TABLE 5. EFFECT OF STILBESTROL TREATMENT ON DIGESTION AND NITROGEN BALANCE (DAILY BASIS)

Item	Control	Treated
Ration	Corn alfalfa hay	Corn alfalfa hay
Protein content (n×6.25) percent	14.25	14.25
Number of lambs	5	4
Daily dry matter intake, gms.	830.6	834.0
Av. digestibility coefficients, percent:		
Dry matter	75.19	74.50
Protein (n×6.25)	65.05	64.74
Ether extract	69.72	68.37
Crude fiber	51.41	49.41
N. F. E.	86.88	87.02
Ml. urine voided	393.1	345.6
Mg. N. per ml. urine	25.56	26.29
Nitrogen intake, gms.	18.5	18.9
Nitrogen in feces, gms.	5.9	6.1
Nitrogen in urine, gms.	9.8	8.8
Nitrogen retained, gms.	2.8	4.0

between the two groups was due to the smaller amount of urine voided and not due to a lower concentration of nitrogen in the urine. Clegg (1952) reported that stilbestrol treated steers retained almost twice as much nitrogen as untreated steers. Furthermore, the amount of nitrogen excreted via the feces was about equal between the two groups but that the difference was due almost entirely to a smaller amount lost via the urine. Whitehair *et al.* (1953) reported an 83 percent increase in nitrogen retention by lambs treated with stilbestrol. Neither of the two investigations reported the amount of urine excreted. A lower concentration of nitrogen in the urine resulting in greater nitrogen retention would suggest an increase in protein anabolism. The smaller volume of urine excreted by the treated lambs in this

trial resulted in approximately 30 percent greater nitrogen retention. Whether the lower urine excretion was due to a higher water retention in the body tissue or a lower intake of water was not ascertained.

Field Studies of Stilbestrol Treated Lambs

During the winter of 1951 the author had the opportunity to observe the effect of treatment with 12 mg. of stilbestrol on approximately 9,000 lambs. The lambs received a ration of wet corn containing approximately 50 percent moisture, alfalfa hay of rather poor quality and minerals. Water was hauled several miles to the lambs. These conditions are mentioned specifically inasmuch as they are rather marked deviations from the type of feed and watering conditions usually prevailing. Ten days after treatment a large number of these lambs developed blockage of the urinary tract. This was diagnosed as urinary calculi and upon post mortem examination a few calcium stones were found. However the primary cause for the urinary blockage was an inflammation in the urinary tract. The cases of blockage of the urinary tract continued at a high rate for about 90 days. In addition to the urinary blockage many of the lambs developed severe prolapse of the rectum in case of wethers and of the vagina and uterus in case of the ewe lambs. A high death loss resulted totaling approximately 2000 lambs. On April 22, these lambs were shipped to a lamb dealer in the corn belt; 6369 lambs were received and in apparent good health. Three or four days after arrival at the feed lot the lambs began to show evidence of prolapse and heavy death losses occurred. Before marketing the healthy lambs, they were "mouthed" to see that they had a lamb mouth. While all the lambs showed a lamb mouth 23 percent failed to break at the break joint.

In another field trial in which about 3500 lambs were treated with 12 mg. of stilbestrol a high incidence of prolapse occurred which resulted in about a 10 percent death loss. It is unfortunate that in neither case was part of the lambs untreated and left as a control group. While the very unusual feeding conditions that existed during the fall of 1951 may have had some effect on the severe outbreak of prolapse, the administration of stilbestrol no doubt was a very important factor in the outbreak. Bell *et al.* (1953) observed similar conditions at these and post-mortem examination showed an enlargement of the cowpers and prostate glands and partial closure of the urinary tract.

Summary

Subcutaneous implantation of 12 mg. stilbestrol in the jaw of suckling lambs failed to increase rate of gain in suckling lambs 2½–3 months of age. A slight but statistically insignificant increase resulted when suckling lambs 3½–4 months of age were treated. General type was not affected by treatment but an increase in the size of the mammary glands and formation of normal appearing milk was evident in the treated lambs. Testes growth was arrested but approximately 4–5 months post-treatment the testes appeared normal.

Treatment of fattening lambs with 12 mg. stilbestrol increased rate of gain and feed efficiency significantly. Carcass grade was lowered considerably and carcass yield slightly. Treated lambs tended to shrink more following slaughter than control lambs. Total cooking losses including water vapor and drippings were of about the same magnitude in both groups.

There was no difference in digestibility of the feed nutrients by the lambs in the two groups. Milligrams of nitrogen per milliliter of urine were approximately the same for both groups. However the treated lambs excreted considerably less urine and consequently excreted less nitrogen. Nitrogen retention was approximately 30 percent greater in the treated lambs.

A severe outbreak of prolapse of the rectum, and uterus resulting in urinary blockage and death occurred in a band of 9,000 lambs treated with 12 mg. of stilbestrol.

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EFFECT OF LEVEL OF STILBESTROL ON GROWTH AND FATTENING OF LAMBS [1]

R. M. JORDAN [2]

South Dakota Agricultural Experiment Station

MARKED increases in rate of growth and feed efficiency in sheep have resulted from subcutaneous implantations of stilbestrol pellets (Andrews *et al.*, 1949; Jordan, 1950; O'Mary *et al.*, 1952; and Means *et al.*, 1953). Twelve milligrams of stilbestrol has been the usual dosage used; however, Andrews *et al.* (1949) and Means *et al.* (1953) treated lambs with 12 and 24 milligrams of stilbestrol. A slightly greater response from the larger dose was obtained. Subcutaneous implantation of 12 mg. of stilbestrol has caused severe outbreaks of prolapse of the uterus and rectum, blockage of the urinary tract and earlier closure of the break joint of fattening lambs fed approximately 150 days after implantation (Jordan, 1952).

Two experiments were conducted at the South Dakota Agricultural Experiment Station to determine the response from lower levels of stilbestrol and the duration of growth response.

Material and Methods

In the first experiment two groups of 25 western lambs averaging 70 pounds each were used. In the second trial three groups of 36 western lambs averaging 73 pounds each were fed. The treatments were as follows: Experiment I, Group I, controls; Group II, 6 mg. of stilbestrol. In the second experiment Groups I and II were treated the same as in the first experiment. Group III was treated with 12 mg. of stilbestrol. In both trials the stilbestrol was administered in the jaw.

In the first experiment the lambs were full-fed in a shed and received a ration of shelled corn, brome hay and soybean meal and had access to salt and a salt-bonemeal mixture. The feeding period was 81 days. In the second experiment the lambs had only a board fence for protection. They were full-fed for 80 days a ration of

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shelled corn, alfalfa hay and had access to salt and a salt-bonemeal lick.

Individual carcass grade and average carcass yield were obtained at the time of slaughter.

TABLE 1. EFFECT OF STILBESTROL ON FATTENING LAMBS

	Experiment I		Experiment II		
Item	Lot I Control	Lot II 6 mg. Stilbestrol	Lot I Control	Lot II 6 mg. Stilbestrol	Lot III 12 mg. Stilbestrol
No. of lambs	25	25	36	36	36
Days fed	81	81	80	80	80
Av. initial wt., lbs.	71.9	68.6	74.7	73.4	71.8
Av. final wt., lbs.	100.6	107.3	95.4	111.4	111.4
Gain/lamb, lbs.	28.7	38.7	20.7	38.0	39.6
Av. daily gain	.35	.48	.26	.48	.50
Death loss	0	0	0	0	0
Av. daily feed consumed					
Grain	1.38	1.39	.94	1.3	1.3
Hay	1.84	1.84	1.9	1.9	1.9
Protein	.2	.2	....	....	....
Feed per 100 lb. gain					
Grain	385.3	287.3	343.0	247.9	238.1
Hay	520.3	390.1	780.7	418.7	401.8
Protein	55.9	41.3	....	....	....
Selling price	19.00	19.00	20.25	20.00	19.75
Carcass yield	49.1	47.9	47.9	45.2	45.1
Carcass grade					
Prime	..	..	8	1	..
Choice	17	6	27	19	17
Good	8	19	1	14	16
Utility	..	..	..	..	3

Results and Discussion

Growth Rate

The results of treating lambs with 6 mg. and 12 mg. of stilbestrol are shown in table 1. In the first experiment the treated lambs gained .13 pound faster per lamb daily than the control lambs (controls .35 pound *vs.* treated .48 pound per lamb daily). This difference was highly significant. The difference in rate of gain between the treated and untreated lambs in this trial is greater than has been true of previous trials conducted at this station in which 12 mg.

of stilbestrol was used. The effect of the stilbestrol was still evident during the last 25 days of the experiment as the difference in rate of gain between the two groups during that period was .07 pound greater in the treated group.

In the second experiment the average daily gain was: controls, 0.26 pound; 6 mg. of stilbestrol, 0.48 pound, and 12 mg. of stilbestrol, 0.50 pound. The difference in rate of gain for the groups that received stilbestrol as compared to the controls was highly significant. The difference in daily rate of gain between Group II and III was not significant. The difference in average daily gain between the control group and the group receiving 6 mg. of stilbestrol during the last 17 days was .26 pound suggesting that the stilbestrol was still exerting considerable effect on the growth rate of the treated lambs at that time.

Feed Consumption and Efficiency

In the first trial feed consumption in both lots was about the same. This is in agreement with previous work at this station (Jordan, 1950). However, in the second experiment, feed consumption was considerably greater in the treated groups. Feed efficiency was increased in both trials by stilbestrol treatment. In the first trial the treated lambs required 72 percent as much grain and 75 percent as much hay as the control lambs per 100 pounds of gain. In the second experiment only about 70 percent as much grain and about 53 percent as much hay was required per 100 pounds of gain by the treated lambs as compared to the control lambs.

Carcass Data

The effect of 6 and 12 mg. of stilbestrol on carcass grade and yield is shown in table 1. In the first experiment the carcass yield of the control and treated lambs was 49.1 and 47.9 percent respectively. In the second experiment the carcass yield for the three groups was as follows: control, 47.9; 6 mg., 45.2, and 12 mg., 45.1 percent. Carcass grade was lower in both experiments among the treated lambs. There was little difference in carcass grade between the group treated with 6 mg. of stilbestrol and those receiving 12 mg. of stilbestrol. No cases of prolapse of the rectum or vagina or closure of the break joint was evident in any of the lambs. The length of the feeding period may not have been long enough for

differences in undesirable effects due to different levels of treatment to appear.

Summary

Fattening lambs treated with subcutaneous implantations of either 6 or 12 mg. of stilbestrol gained significantly faster than the control group and were more efficient in feed utilization.

Carcass yield and grade were consistently lower among the treated lambs.

There was little difference in rate of gain, feed efficiency, feed consumption or carcass grade and yield between the lambs treated with 6 mg. of stilbestrol and those treated with 12 mg. of stilbestrol.

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RELATIONSHIPS BETWEEN LIBIDO, SEMEN CHARACTERISTICS AND FERTILITY IN RANGE RAMS

E. L. Wiggins, C. E. Terrill and L. O. Emik [1]

U. S. Department of Agriculture [2]

ALTHOUGH there is considerable information available on the characteristics of ram semen and on factors affecting semen production in rams (see Anderson, 1945), there appears to be very little information on the relationships between semen characteristics and fertility or between libido and fertility. McKenzie and Phillips (1934) and Gunn *et al.* (1942) have presented evidence of an inverse relationship between the percentage of abnormal sperm and fertility. McKenzie and Berliner (1937) and Webster (1937) reported that rams producing semen with an alkaline reaction were of poor fertility. Terrill (1937) compared the semen, immediately after the close of the breeding season, of five rams from which 95 percent or more of the ewes became pregnant (average 97.8 percent) with that of four rams from which less than 95 percent of the ewes became pregnant (average 87.7 percent). On the average the semen of the rams in the upper group excelled that of rams in the lower group in volume, sperm concentration, number of sperm per ejaculate, motility score, percent motile sperm, maintenance of motility under storage and percentage of normal sperm. This was not true, however, of each individual ram within the groups, i.e., the semen of some rams in the lower group excelled that of some rams in the upper group in certain respects. The rams in the lower group also had a greater average number of ejaculates (3.0 *vs.* 2.2) per 30-minute trial.

Quite a number of laboratory tests have been developed for the evaluation of dairy bull semen. The literature pertaining to these tests has been reviewed by Anderson (1945), Erb *et al.* (1950) and Branton *et al.* (1951). From their discussions it appears fairly clear that no single, rapid, laboratory test having a high predictive value of the potential fertility is available at present.

Routine examinations of the semen of all prospective breeding rams at the U. S. Sheep Experiment Station have been made each year since 1936. In general only those rams whose semen appeared to indi-

[1] L. O. Emik is now with the U. S. Public Health Service, Atlanta, Georgia.

[2] U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho in cooperation with the University of Idaho.

cate that they would be highly fertile were used in breeding, but the nature of the breeding program has necessitated the use of some rams with semen of questionable quality. In addition there was considerable variation in the quality of semen of the other rams used although all were considered to be potentially highly fertile. Libido was not considered in evaluating prospective breeding rams except to require that the ram produce at least one, and preferably two, ejaculates in a 30-minute period. In view of this variation in semen characteristics and libido of the rams used, it was thought that a study of the relationships between these factors and breeding records of the rams would yield information on the usefulness of the different tests employed for selecting highly fertile rams.

Materials and Methods

Data on prebreeding semen characteristics and subsequent breeding performance of 1109 rams bred in 1309 breeding pens to 31,473 ewes from 1936–1950, inclusive, were available for study. Since some of the rams and most of the ewes were in the breeding flock for more than 1 year, these figures are not the numbers of different individual animals used in the study but rather the numbers of independent observations for the various items studied. The rams used were of the Rambouillet, Columbia, Targhee and Corriedale breeds with only a few exceptions. The ages of the rams ranged from about 7 months (ram lambs) to 9 years. In the earlier years many of the rams used were 3 or 4 years old, but in later years the majority were 1 year old and few were over 2 years old.

Both rams and ewes were fed hay in dry-lot during the winter and grazed on the range the remainder of the year. In most years the rams were fed a moderate amount of grain for 1 to 2 months before the beginning of the breeding season in the fall. The ewes were fed some supplemental feed for a 4- to 6-week period before lambing each year.

Single ejaculates were collected from ewes in diestrus by the method outlined by Terrill (1937). The interval from the time that the ram was placed with the ewe until each ejaculate was produced was recorded as the "ejaculation time" for that ejaculate. From 1936 through 1947 the rams remained with the ewes for a 30-minute period and were allowed to mate as many times as they desired. Usually rams that mated only once were retested until they produced at least two ejaculates during the 30-minute period. Beginning in 1948, the 30-minute

time limit was discarded and three ejaculates were collected from all rams.

The semen was collected in graduated test tubes and the volume recorded to the nearest 0.1 cc. The method of scoring sperm activity was that described by Terrill (1937). Briefly, the degree of activity (motility score) was scored from 1 to 6 with a score of 1 denoting the highest degree of activity and a score of 6 denoting no activity; the percentage of motile sperm was estimated to the nearest 20 percent. EMC's (estimated motility counts) which combine motility score and percentage of motile sperm into a single figure were calculated by a method developed at this Station by Emik, Terrill, and Sidwell (1948). Appearance and viscosity was scored as follows:

Very thick	1
Creamy thick	2
Creamy fluid	3
Milky thin	4
Watery	5

The pH was estimated to the nearest 0.5 unit (e.g., 6.0, 6.5, 7.0, etc.) with test paper. From 1936 to 1944 sperm concentration was determined by hemacytometer counts. After 1944 sperm concentration was estimated from turbidity readings in a colorimeter as described by Emik and Sidwell (1947). Total number of sperm was obtained by multiplying the sperm concentration by the volume of semen. The procedure of the examination for sperm morphology followed from 1936 to 1941 was essentially the same as described by Terrill (1937). Beginning in 1942, the opal blue-eosin stain for differentiating live and dead sperm (Lasley *et al.*, 1942) was adopted and sperm morphology counts were also made from those slides. Detailed morphology or "live-dead" counts were not made after 1944, although these traits were roughly appraised in evaluating the semen.

Averages of the ejaculates produced in a 30-minute period (in the earlier years) or of the three ejaculates (in the later years) were used for all characteristics except ejaculation times, the number of ejaculates and the total number of sperm per trial. If a ram was retested for any reason, only data from the last test before the beginning of the breeding season was used in this study.

The rams were allowed to run with the ewes in panel pens or small pastures during the breeding season, which averaged about 30 days in length. During the breeding season the rams received the same feed as the ewes (hay in pens and forage in pastures) except for ram lambs which were fed a moderate amount of grain in addition. The

number of ewes bred to each ram ranged from 5 to 65. Matings consisted of inbred lines, linecrosses, test pens and breed crosses.

Three criteria of fertility were used in studying the relationships of various factors to fertility:

1. Percentage of ewes lambing of ewes present at lambing.
2. Percentage of live lambs of total lambs born.
3. Percentage of lambs weaned of live lambs born.

TABLE 1. MEANS, RANGES AND STANDARD DEVIATIONS OF ITEMS STUDIED

Item	Mean	Range	Standard Deviation
Ejaculation time I (minutes)	6.94	1–242	5.20
Ejaculation time II (minutes)	17.36	2–312	20.18
Ejaculation time III (minutes)	28.05	4–367	25.01
Number of ejaculates/trial	2.87	1–6	0.73
Viscosity score	3.05	1.0–5.0	0.33
pH	6.59	5.5–8.0	0.48
Volume of semen (cc.)	0.86	0.15–2.30	0.31
Motility score	1.31	1.0–5.0	0.49
Percentage of motile sperm	87.18	0–100	13.28
Estimated motility count	93.16	0–102	10.79
Concentration/cc. ($\times 10^7$)	298.60	35–718	110.85
Total sperm/trial ($\times 10^7$)	742.04	26–3796	448.14
Percentage of normal sperm	89.03	5–100	7.25
Percentage of abnormal heads	0.73	0–95	3.89
Percentage of live sperm	80.16	18–98	10.79
Percentage of live-normal sperm	79.00	4–97	11.65
Age of ram (years)	1.70	<1–9	1.13
Inbreeding of ram (percent)	9.46	0–45	2.66
Number of ewes bred/pen	24.04	1–65	6.86
Percentage of ewes lambing	90.43	0–100	12.38
Percentage of live lambs	92.54	0–100	10.44
Percentage of lambs weaned	82.52	0–100	12.12

Correlation and regression techniques as described by Snedecor (1946) were employed in the analysis. All sums of squares and cross products were calculated on a within-year, within-breed, within-type of mating (inbred-line, cross-line, etc.) basis and the net sums of squares and cross products for each group were pooled to obtain average, within-group correlations.

Results and Discussion

Means of Items Studied

Means, ranges and standard deviations of all items considered in studying the relationships of different factors to fertility are presented

in table 1. They are presented merely to give a picture of the libido and semen characteristics of the rams used and the fertility of the flock during the period of study. It is emphasized that the means of ram traits are from a selected sample and are probably somewhat higher than would be found in a general population of rams.

Percentage of Ewes Lambing

During the 15 years the average percentage of ewes lambing per pen was 90.43 (table 1). There were 306 pens (23.38 percent) in which all ewes lambed (table 2). About 68 percent of the pens had a lambing percentage of 90 or higher and about 91 percent had a percentage of 80 or higher. There were 10 pens (0.76 percent) in which no ewes lambed. Since two of the dry pens contained only one ewe each and the rams used settled ewes bred in other pens the same year, dryness in these pens is probably largely a matter of chance. Six rams were responsible for the remaining eight dry pens since one ram was bred in three different pens the same year. The numbers of ewes bred to these rams ranged from 15 to 31. Of the six rams only two were considered to be of doubtful fertility at the time of use. This indicates that either the semen characteristics of the rams changed drastically in the short interval between the time of testing and the beginning of breeding or that there are one or more other semen characteristics not evaluated by, or highly correlated with, the tests employed here that bear an important relationship to fertility.

Relationships between Libido and Percentage of Ewes Lambing

Libido was measured in these rams by the time required to produce the successive ejaculates (ejaculation times) in all years and by the number of ejaculates produced in a 30-minute period from 1936 to 1947.

There were significant, negative correlations between each of the ejaculation times and the percentage of ewes lambing, i.e., a decrease in ejaculation time was accompanied by an increase in the percentage of ewes lambing (table 3). There was also a significant positive correlation between the number of ejaculates produced in a 30-minute period and the percentage of ewes lambing. Thus it appears that rams having a high degree of libido, as expressed by a willingness to mate soon after being exposed to an anestrual ewe, and by a willingness to serve several times in a 30-minute period, are more fertile than rams having less libido. Differences between the perform-

TABLE 2. DISTRIBUTION OF PERCENTAGES OF EWES LAMBING PER PEN, 1936–1950, INCLUSIVE [1]

	Number of Pens Having a Percentage of Ewes Lambing of:												
	0	1–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100	Total
Total	10	0	0	1	5	6	12	14	70	300	585	306	1309
Percent	0.76	0.00	0.00	0.08	0.38	0.46	0.92	1.07	5.35	22.92	44.69	23.38	....

[1] Average percent of ewes lambing per pen = 90.43.

ances of rams in finding and covering ewes in heat might account for much of the difference in the percentages of ewes lambing in different pens, although this seems unlikely because the bulk of the breeding was done in small panel pens to moderately sized groups of ewes (the average number of ewes per ram was 24). It also seems

TABLE 3. SIMPLE CORRELATION AND REGRESSION COEFFICIENTS OF LIBIDO, SEMEN CHARACTERISTICS AND OTHER FACTORS, WITH BREEDING RECORDS OF RAMS

Item	Degrees of freedom	Percentage of ewes lambing		Percentage of live lambs		Percentage of lambs weaned	
		r	b	r	b	r	b
Ejaculation time I	1091	−0.124**	−0.093	−0.042	−0.027	0.036	0.026
Ejaculation time II	1040	−0.150**	−0.092	−0.039	−0.020	0.007	0.042
Ejaculation time III	727	−0.098*	−0.050	−0.032	−0.018	0.055	0.030
No. of ejaculates	1091	0.081**	1.378	−0.019	−0.264	−0.024	−0.390
Viscosity score	1091	0.019	0.708	0.023	0.718	−0.008	0.297
pH	1091	−0.057	−1.470	−0.007	−0.158	−0.074*	−1.864
Volume of semen	1091	0.062*	2.479	0.100**	3.376	−0.019	−0.742
Motility score	1091	−0.057	−1.464	−0.048	−1.027	0.014	0.339
% Motile sperm	1091	0.060	0.056	0.036	0.029	−0.145**	−0.133
E M C	1091	0.077*	0.088	0.094**	0.091	−0.049	−0.055
Concentration/cc.	1091	0.023	0.002	0.019	0.002	−0.033	−0.004
Total sperm	1091	0.057	0.002	0.044	0.001	−0.022	−0.001
% Normal	596	0.432**	0.618	0.317**	0.366	−0.008	−0.010
% Abnormal heads	596	−0.350**	−0.934	−0.462**	−0.994	−0.363**	−0.884
% Live sperm	238	0.087	0.097	0.072	0.071	−0.004	−0.006
% Live-normal sperm	238	0.292**	0.299	0.316**	0.286	0.181**	0.232
Age of ram	1091	0.040	0.434	−0.009	−0.080	−0.066*	−0.708
Inbreeding of ram	1091	−0.047	−0.069	−0.069*	−0.085	−0.097**	−0.140
Number of ewes bred	1091	0.065*	0.117	.....	.....	.....	.....
% Live lambs	1091	0.554**	0.656	.....	.....	.....	.....
% Lambs weaned	1091	0.304**	0.311	0.444**	0.515		

* Significant at the 5% level.
** Significant at the 1% level.

unlikely that in pens of this size many ewes in heat would go unnoticed by the ram or would not be served by the ram because of other ewes, more attractive to him, being in heat at the same time. However, very little information is available on the latter point. Hafez (1951) has reported that ewes differed in their mating behavior (intensity of heat) and also that rams showed different intensities of "sex drive" toward different ewes, i.e., some ewes were more attractive to the ram than were other ewes. More information on mating behavior of rams under various conditions would be highly desirable. Another possible explanation is that the rams with more libido tended to produce better semen than rams exhibiting less libido. To check on this possibility, correlations between the measures of libido and the semen traits which were significantly associated with fertility

were calculated. There was a tendency for the signs of the correlation coefficients to be in the direction of rams with more libido having better semen, but there were numerous exceptions. In addition the correlations were very low and most of them were not significant. Thus it appears that there is little relationship between libido and semen quality as evaluated by a single prebreeding trial. This does not rule out the possibility that rams with more libido tend to produce higher quality semen over the course of the breeding season than rams with less libido, but systematic testing of rams during the breeding season would be necessary to establish this point.

Relationships between Semen Characteristics and Percentage of Ewes Lambing

Volume of semen was significantly correlated, positively, with percentage of ewes lambing. EMC was also significantly correlated with percentage of ewes lambing although neither of its components (motility score or percent motile sperm) was. However, correlations of both of the latter with percentage of ewes lambing approached significance. Percentage of normal sperm, percentage of abnormal heads and percentage of live-normal sperm were significantly correlated with percentage of ewes lambing. This is in agreement with the reports of McKenzie and Phillips (1934) and Gunn *et al.* (1942). However, percentage of live sperm was not significantly associated with fertility, and it appears likely that the significant correlation between percentage of live-normal sperm and fertility is due entirely to the relationship between percentage of live-normal sperm and percentage of normal sperm. When the percentage of normal sperm was held constant, the partial correlation between percentage of live-normal sperm and percentage of ewes lambing was only 0.02.

None of the other semen characteristics studied (viscosity score, pH, motility score, percentage of motile sperm, sperm concentration or total sperm) were significantly correlated with percentage of ewes lambing in this study.

Relationships of Other Factors to Percentage of Ewes Lambing

In addition to libido and semen characteristics of the rams, the relationships of age and inbreeding of the rams and the number of ewes per ram with percentage of ewes lambing were studied. Age of ram and inbreeding of the ram were not significantly correlated with percentage of ewes lambing.

There was a significant positive correlation between the number of ewes bred and percentage of ewes lambing, i.e., fertility tended to be higher among rams bred to larger numbers of ewes. There are several possible causes for this unexpected relationship. Some of the rams used in small breeding pens had semen of poorer than average quality. This is partly a result of there being some willingness to risk the use of a ram with high over-all merit, but with semen of only fair quality, in a small pen but not in a large pen. Also in a few cases where none of the rams available for use had semen of good quality, the ewes were divided and two rams were used with the hope that at least one of them would be fertile. Also many of the matings were within inbred lines. If some lines were small because of poor reproductive performance and other lines were larger than average because of an exceptionally good reproductive performance, a spurious positive correlation between number of ewes bred and percentage of ewes lambing could result. In a study of reproductive performance in this flock during an earlier period, Terrill and Stoehr (1939) found an inverse relationship ($r=-0.11$) between the number of ewes bred and the percentage of ewes lambing. In their study the average number of ewes per ram was 48 and the maximum number bred to one ram was 93, while in this study the corresponding figures were 24 and 65.

Relationships between Various Factors and Percentages of Live Lambs and Percentage of Lambs Weaned

None of the measures of libido (the three ejaculation times or the number of ejaculates produced in a 30-minute period) were significantly associated with either the percentage of live lambs born or the percentage of lambs weaned of live lambs born.

Volume of semen, EMC, percentage of normal sperm, percentage of abnormal heads and percentage of live-normal sperm were all significantly correlated with percentage of live lambs. These are the same traits that were significantly correlated with percentage of ewes lambing. Percentage of motile sperm, pH, percentage of abnormal heads and percentage of live-normal sperm were significantly correlated with percentage of lambs weaned.

There were significant negative correlations between inbreeding of the ram and percentage of live lambs, and inbreeding of the ram and percentage of lambs weaned. This is probably because the more highly inbred rams tended to produce more highly inbred offspring.

Unpublished studies at this Station have shown that inbreeding has a depressing effect on both percentage of live lambs born and percentage of lambs weaned.

The correlations between percentage of ewes lambing and percentage of live lambs, and between percentage of ewes lambing and percentage of lambs weaned, were both highly significant (0.55 and 0.30, respectively). The corresponding regression coefficients were 0.47 and 0.30, i.e., an increase of 1 percent in the percentage of ewes lambing was accompanied by an increase of 0.47 percent in live lambs born and 0.30 percent in lambs weaned. There was also a highly significant correlation (r=0.44, b=0.51) between percentage of live lambs and percentage of lambs weaned of live lambs born. Thus it would appear that a highly fertile ram has an advantage over a less fertile ram not only in the percentage of ewes lambing but also in the percentage of live lambs dropped and in the percentage of lambs weaned by ewes that do lamb. This can be at least partly explained if it is assumed that fertilization rates are fairly uniform from one pen to another and differences in embryonic and fetal death rates are major causes of variation in fertility in different breeding pens. If in some pens there is little prenatal death, most of the lambs are born alive and fertility of the pen is high. In other pens there is considerable prenatal death; if prenatal death occurs early in gestation, the fetus is resorbed and, since the breeding season is restricted, the ewe often has no opportunity to rebreed and is counted as a "dry" ewe at lambing time. If fetal death occurs late in gestation, the dead fetus is dropped at or near term and the ewe is counted as having dropped a dead lamb. The result is that in pens where the prenatal death rate is high the percentage of ewes lambing and the percentage of live lambs born are both lower than in pens where the prenatal death rate is lower. Therefore, two groups of ewes bred to different rams might have the same initial fertilization rate but differ markedly in the percentage of ewes lambing because they had different prenatal death rates.

Discussion

It should be borne in mind, when evaluating these results, that the practice of using, insofar as possible, only rams that appeared to have semen of high quality would tend to obscure the relationships between semen characteristics and the subsequent breeding performance of the rams. This same factor may be partly responsible for

the generally low correlations between semen quality tests and fertility of samples of dairy bull semen reported by many investigators. The data used in most of these studies were obtained from artificial insemination rings, and it seems likely that most rings would be reluctant to ship samples of semen that were of poor quality or from bulls with poor breeding records. The practice of using only "good" samples of semen from relatively highly fertile bulls would almost certainly reduce the relationships between semen quality tests and fertility that would exist in an unselected population of semen samples from an unselected group of bulls.

Many of the rams were bred to small numbers of ewes. It is entirely possible that "ewe differences" in fertility may have tended to obscure real relationships between semen characteristics and breeding records of the rams in some pens. In addition a small number of ewes may not be adequate to bring out differences in potential fertility of different rams. For example, a ram with semen of mediocre quality could have the same conception rate in a pen of 15 or 20 ewes as another ram with semen of much higher quality, but could have a much lower conception rate in a pen of 40 or 50 ewes. As a matter of fact, the significant positive correlation between the number of ewes bred and the percentage of ewes lambing is good evidence that very few rams were bred to the maximum number of ewes that one ram could be expected to settle in a 30-day breeding season. Also a more precise measure of breeding efficiency (e.g., percentage of ewes settling on first service, or services required per conception) might have made possible the detection of differences in breeding efficiency in different rams that had the same apparent efficiency when the less precise measure, "percentage of ewes lambing," was used. Unfortunately, dates of breeding of individual ewes were kept for only 2 years during the period of study, and it is doubtful that enough data are available to yield much information on this point.

Terrill and Stoehr (1939) found about 1 percent of dry pens in this flock where pen mating was practiced, but the semen of the rams was not examined before breeding. However, there have been extensive changes in management and breeding practices since that study was made. Therefore, it is not possible to determine how successful the practice of examining the semen of all prospective breeding rams has been in locating potentially sterile rams. Information on this point could be best obtained by evaluating the potential fertility of the rams on the basis of prebreeding semen examinations but then

using the rams irrespective of the quality of their semen. It would seem reasonable to assume that the percentage of ewes lambing has been increased in proportion to the amount of attention paid to the semen traits that were significantly associated with fertility when selecting or rejecting a ram for use in breeding on the basis of his semen. It would appear, however, that in view of the relatively low order of the correlation coefficients between semen characteristics and percentage of ewes lambing (even though some are significant), only a slight increase in fertility in this flock could be expected to result from measures designed to improve further the semen quality in the rams.

It is emphasized that, for the reasons stated above, any relationships between semen characteristics and breeding records in this flock would be almost certain to be low. Some of the other commonly accepted criteria of semen quality (e.g., motility, sperm concentration, etc.) may have real relationships to fertility although they were not found to have in this study.

Summary

The relationships of libido, semen characteristics and other factors to breeding performance of 1109 rams, consisting mainly of the Rambouillet, Columbia, Targhee and Corriedale breeds, mated in 1309 pens to 31,473 ewes over a 15-year period were studied.

The data indicated that libido, as measured by the time required to produce successive ejaculates and by the number of ejaculates produced in a 30-minute period, had a significant relationship to fertility.

Of the various semen characteristics studied (including viscosity, pH, volume of semen, motility score, percentage of motile sperm, estimated motility count, or EMC, sperm concentration, total sperm produced per trial, percentage of normal sperm, percentage of abnormal heads, percentage of live sperm and percentage of live-normal sperm) only volume of semen, EMC, percentage of normal sperm, percentage of abnormal heads and percentage of live-normal sperm were significantly correlated with the percentage of ewes lambing.

The inbreeding of the ram had a significant depressing effect on the percentage of live lambs and the percentage of lambs weaned but not on the percentage of ewes lambing.

The percentage of ewes lambing was significantly correlated with the percentage of live lambs and with the percentage of lambs

weaned. The percentage of live lambs was also significantly correlated with the percentage of lambs weaned.

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EFFECTS OF SOME GENETIC AND ENVIRONMENTAL FACTORS ON YEARLING TRAITS OF NAVAJO AND NAVAJO CROSSBRED EWES [1]

DONALD A. PRICE,[2] GEORGE M. SIDWELL and JAMES O. GRANDSTAFF [3]

U. S. Departments of Agriculture and the Interior

ALTHOUGH most of the culling in range sheep production takes place at weaning time, some further selection can be made at yearling age. Many environmental factors can influence the performance of young sheep, thereby obscuring genetic merit and thus reducing the progress which might be accomplished by selection.

The purpose of this study was to measure the effect of several environmental sources of variation and of the differences between several breeding groups on staple length, on grease and clean fleece weight, on body weight, on body type and on condition scores, all observed when the ewes were yearlings. The environmental factors studied were age of dam, type of birth and rearing, year in which the ewes became yearlings, and age when the record was made.

Description of Data

The data were taken on 917 yearling ewes which were retained from a total of 1325 ewe lambs weaned. Since these ewes are survivors of some selection, presumably based in part on the traits studied, the data are somewhat less variable than if no selection had been practiced. The ewes were born in May for each of the three years under study. Shearing was in the last 10 days in April. Each fleece was weighed to the nearest tenth of a pound. Just prior to shearing, a small and a large wool sample were clipped from the mid-side of each ewe. The large sample was scoured and from this the clean fleece yield was calculated. Staple length was measured on the small sample to the nearest mm. Body weight, type scores and condition scores were taken in June. The scoring system was the same for both type and condition. Ewes considered as having the highest merit was

[1] The data were collected at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, under authority of the Bankhead-Jones Act, by the Bureau of Animal Industry, U. S. Department of Agriculture, in cooperation with the Bureau of Indian Affairs, U. S. Department of Interior, and the New Mexico Agricultural Experiment Station.

[2] Present address, 631 East Ash, Salina, Kansas.

[3] Present position, Administrator, Office of Experiment Stations, Agricultural Research Administration, U. S. Department of Agriculture, Washington, D. C.

given a score of 1 and those of the lowest merit a score of 5. By assigning plus and minus values to each whole unit, a scoring range of 15 classes was obtained. Very few dams older than 7 years were available for this study. Since only a small difference due to dams 3 years of age and dams 4, 5 and 6 years of age was observed in the traits of these ewes at weaning time, only two age-of-dam groups were considered in this study. All dams lambing at two years of age were classified as young, while those lambing at three years of age and over were classified as mature. The different breeding groups studied were:

1. Navajo Rams×Navajo Ewes
2. Columbia Rams×Navajo Ewes
3. Romney Rams×Navajo Ewes
4. Lincoln Rams×Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
5. Cotswold Rams×Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
6. Rams ½ Cotswold, ¼ Navajo, ⅛ Corriedale, ⅛ Romney× Ewes ½ Columbia, ½ Navajo
7. Rams ½ Columbia, ½ Navajo×Ewes ½ Cotswold, ¼ Navajo, ⅛ Corriedale, ⅛ Romney
8. Rams ½ Romney, ½ Navajo×Ewes ½ Lincoln, ¼ Navajo, ⅛ Corriedale, ⅛ Romney
9. Rams ½ Lincoln, ¼ Navajo, ⅛ Corriedale, ⅛ Romney×Ewes ½ Romney, ½ Navajo
10. Targhee Rams×Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
11. Merino Ram×Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
12. Debouillet Ram×Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
13. Composite of Ewes from groups 6, 7, 8 and 9

Method of Analysis

The numbers of ewes in each of the various classifications are listed in table 1. The numbers 1 to 13 in the first column of this table indicate the various breeding groups as outlined previously in this report. The method of analysis used was the method of least squares suggested by Yates (1934) and extended by Hazel (1946). This method was designed for data multiply classified and with unequal numbers in the different subclasses. In this method constants are fitted for each of the independent variables which, in this case, are the measured environmental factors and the different breeding groups already listed.

Results and Discussion

Tables 2, 3 and 4 summarize the pertinent data. Table 2 shows for all traits the mean, the standard deviation, and the least squares estimates of the amount by which each subclass of the five major

TABLE 1. NUMBERS OF YEARLING EWES, ASSEMBLED ACCORDING TO BREEDING, AGE OF DAM, TYPE OF BIRTH AND REARING, AND YEARS

Breeding Group	Age of Dam		Type of Birth and Rearing			Years		
	Young Dams	Mature Dams	Singles	Twins	Twins Raised as Singles	1948	1949	1950
1	31	135	60	86	20	69	52	45
2	21	118	71	58	14	42	56	41
3	25	101	62	53	11	48	44	34
4	17	158	73	83	19	62	85	28
5	12	87	48	40	11	37	32	30
6	26	16	26	14	2	0	15	27
7	18	14	23	5	4	0	10	22
8	4	0	4	0	0	0	0	4
9	13	0	12	1	0	0	0	13
10	1	21	7	12	3	0	0	22
11	0	13	5	7	1	0	0	13
12	0	11	2	6	3	0	0	11
13	6	69	35	37	3	75	0	0

classifications deviate from the mean. When the deviations in table 2 are added to the means, the expected (least squares) value for the mean measurement of that particular subgroup can be seen. Table 3 shows the analysis of variance, and table 4, the fractions of the total variance in each trait which are attributable to the effects of the factors named. Although nearly all differences are statistically significant, several were too small to be important since they accounted for only a little of the total variation.

Staple Length

Differences between breeding groups were the most important source of variation in staple length accounting for about 24 percent of the total variance. As yearlings, the ewes from mature dams had .18 cm. longer staple than those born of 2 year old ewes. Hazel and Terrill (1946) found this difference to be .12 cm. in Rambouillets. Terrill *et al.* (1947) noted a difference of .46 cm. between Columbia ewes

born of young ewes and those born of mature ewes, but found that among Targhees the young dams produced ewes with .03 cm. longer staple than mature dams. Staple length was .52 and .56 cm. longer in ewes born as singles than in twins and in twins raised as singles,

TABLE 2. SUMMARY OF ESTIMATES OF DEVIATIONS FROM MEAN SHOWING THE VALUE FOR EACH SUBCLASS OF THE MAJOR CLASSIFICATION

Major Classification	Subclass	Estimate of Deviation					
		Staple Length	Grease Fl. Wt.	Clean Fl. Wt.	Body Weight	Type	Condition
Breeding Group	1	.51	−1.36	−.28	−5.31	.51	.48
	2	−.22	.90	.53	2.81	−.15	−.07
	3	−.98	−.23	−.14	−2.18	.00	−.03
	4	1.12	.25	.31	1.12	−.06	.10
	5	2.71	.63	.49	1.03	−.06	.09
	6	.43	−.42	−.06	4.25	−.01	.07
	7	.85	−.26	−.12	2.41	.00	.14
	8	.24	−.66	−.29	−3.74	.11	.19
	9	.39	−1.11	−.42	1.93	.04	.02
	10	−1.86	.34	−.29	2.45	−.22	−.36
	11	−2.05	.98	.15	−2.48	−.14	−.58
	12	−2.47	.19	−.54	2.33	−.20	−.28
	13	1.34	.78	.60	−4.65	.18	.20
Age of Dam	Young Dam	−.09	−.10	.02	−1.55	.01	.02
	Mature Dam	.09	.10	−.02	1.55	−.01	−.02
Type of Birth and Rearing	Singles	.36	.36	.17	2.67	−.19	−.03
	Twins	−.16	−.54	−.18	−3.87	−.09	.08
	Twins Raised as Singles	−.20	.1[illegible]	01	1.20	.28	−.05
Years	1948	.06	−.71	−.58	5.84	.12	−.18
	1949	−.16	−.03	.54	−1.91	−.08	−.06
	1950	.10	.74	.04	−3.93	−.04	.24
Age of Ewe	Regression on Age	.02	.03	02	.12	.00	.00
Mean		10.65	7.44	3.56	86.54	2.43	2.22
Standard Deviation		1.83	1.32	.74	7.18	.36	.39

respectively. Differences from year to year accounted for only .77 percent of the total variation. The regression of staple length on age at sampling was .02 cm. This regression is too small to account for the average yearly staple length of 10.65 cm. Hazel and Terrill (1946) and Terrill *et al.* (1947) noted a similar discrepancy with yearling ewes of Rambouillet, Columbia and Targhee breeding.

Grease Fleece Weight

All factors studied affected grease fleece weight significantly. Differences between breeding groups accounted for more of the total varia-

TABLE 3. SUMMARY OF ANALYSIS OF VARIANCE FOR ENVIRONMENTAL FACTORS AND BREEDING GROUPS

(Mean Squares Only)

Source of Variation	Degrees of Freedom	Staple Length	Grease Fl. Wt.	Clean Fl. Wt.	Body Wt.	Type	Condition
Total	916	6.25	3.15	.84	96.82	.19	.22
Reduction due to fitting all constants	18	151.62**	74.51**	15.99**	2357.14**	3.17**	3.99**
Between Breeding Groups	12	141.11**	50.41**	12.25**	695.85**	3.53**	3.23**
Between Ages of Dams	1	202.61**	222.11**	41.32**	963.87**	.07	.15
Between Types of Birth and Rearing	2	70.64**	74.86**	14.09**	3972.04**	.93**	1.23**
Between Years	2	21.91**	36.76**	14.91**	821.61**	.97**	4.22**
Between Ages of Ewe	1	266.76**	83.85**	21.17**	477.32**	1.21**	.53
Remainder	898	3.34	1.72	.53	51.52	.13	.15

** Signifies probability of chance occurrence $<.01$.

tion than any other factor. Fleeces of ewes from mature dams weighed .20 pounds more than fleeces of ewes from 2 year old dams. Fleeces from those born as singles were .9 pounds heavier than fleeces from twins and .18 pounds heavier than from twins raised as singles. Differences between years accounted for about 2.5 percent of the total variation. Fleece weights averaged .03 pounds heavier per day of extra age at shearing.

Clean Fleece Weight

All of the factors had significant effects upon clean fleece weight. The yearling ewes from young mothers produced slightly heavier clean fleeces than the ewes from mature dams, and the ewes born as

TABLE 4. PERCENTAGE OF TOTAL VARIANCE ATTRIBUTED TO EACH MAIN SOURCE OF VARIATION

Main Source of Variation	Staple Length	Grease Fl. Wt.	Clean Fl. Wt.	Body Weight	Type	Condition
Total effect accounted for	47.7	46.5	37.5	47.8	33.2	35.3
Breeding groups	23.9	21.0	19.2	9.4	24.6	19.0
Age of dam	3.5	7.7	5.4	1.1	.0	.0
Type of birth and rearing	2.5	5.2	3.5	9.0	1.1	1.2
Years	.8	2.6	3.9	1.8	1.1	4.1
Age of ewe	4.7	2.9	2.8	.5	.7	.2
Remainder	52.3	53.5	62.5	52.2	66.8	64.7

singles produced heavier fleeces than twins or twins raised as singles. The regression of clean fleece weight on age at shearing was .02 pounds per day. This regression is too large to have been true for the whole first year of life, since it would have amounted to nearly 7 pounds of clean wool, whereas the average clean fleece weight was 3.56 pounds.

Body Weight

The environmental factors and the difference between breeding groups accounted for about 48 percent of the total variation in body weight. Ewes from mature dams were 3 pounds heavier at yearling age than were the ewes from 2 year old dams. Working with Navajo and Navajo Crossbred weanling lambs, Sidwell and Grandstaff (1949) found that mature ewes produced 3.7 pounds more lamb at weaning age than young ewes. Here, there was a difference of 6.5 pounds between single ewes and twin ewes at yearling age and only 1.47 pounds between singles and twins raised as singles. Sidwell and Grandstaff (1949) found a difference of 11 pounds between singles and twin lambs at weaning time and a 3 pound difference between singles and twins raised singly. Phillips *et al.* (1940) found in range sheep that singles were heavier than twins throughout the first year, but with farm flocks, Phillips and Dawson (1940) found that differences due to type of birth tended to disappear by the time the ewes reached yearling age. Body weight at yearling age increased .12 pounds per day with age at weighing. The regression of weight on age at weaning time, with Navajo and Navajo Crossbred lambs (Sidwell and Grandstaff, 1949) was .37 pounds.

Body Type

The environmental factors and breeding group differences accounted for only about 33 percent of the total variation in body type. Age of dam did not affect scores for body type, single ewes had better type scores than twins or than twins raised as singles. Although the regression of type score on age was statistically significant, this regression is too small to be important practically. Differences between breeding groups accounted for most of the assignable variation.

Condition

Differences between breeding groups accounted for most of the variation in conditions scores, but differences between years were important also. The effect of age of dam was not statistically significant. Single

ewes were in better condition than twins or than twins raised as singles at yearling age. As with body type scores, the regression of condition score on age was not large enough to be important.

Summary

The effects of differences between breeding groups, age of dam, type of birth and rearing, years, and age of the ewe were studied on 917 yearling ewes. The records were taken during the years 1948, 1949 and 1950 at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico. The traits included were staple length, grease and clean fleece weights, body weight, type and condition.

The genetic and environmental factors studied accounted for from 33 to 48 percent of the total variation in the six traits. Differences between breeding groups accounted for from 19 to 24 percent of the variation in all of the traits except body weight. In this trait breeding group difference accounted for only 9.4 percent. Although many of the environmental factors had measurable and statistically significant effects, the differences were too small to be practically important.

The estimates of the amount each factor raises or lowers the trait from the flock mean are shown. Ewes born of mature dams had longer staple, produced more grease wool, had heavier body weight and better type and condition scores than ewes born of 2 year old dams. Single ewes were superior to twin ewes in all traits studied. The age of the ewe had an important effect on all traits except type and condition.

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URINARY CALCULI IN SHEEP[1]

C. E. LINDLEY,[2] E. D. TAYSOM, W. E. HAM and B. H. SCHNEIDER[3]

Washington Agricultural Experiment Station

THE rather high incidence of calculi in the male of beef cattle, sheep and horses causes much concern among livestock operators—especially commercial feeders, but also among breeders of pure bred livestock. Johnson *et al.* (1940) report a 10 percent loss due to urinary calculi in one feeding enterprise involving 2600 wethers. Likewise, urinary calculi are a serious problem in men.

The malady has been reported as being caused by many different factors. Osborne and Mendel (1917) and Higgins (1935) believed that a vitamin A deficiency plays an important role in calculi formation. Schmidt (1941) and Pearson *et al.* (1945) also suggest a vitamin A deficiency as the cause of urinary calculi. However, several workers, including Beeson *et al.* (1943), Eveleth *et al.* (1948) and Lindley *et al.* (1949) present evidence that a vitamin A deficiency is not involved in calculi formation.

Among other possible causes, Newsom (1938) lists hard water, mineral imbalances and urine reaction (pH). This agrees with Eveleth and Millen (1939) who suggest a mineral imbalance as the most plausible factor in calculi formation. They specify a high magnesium content in the ration as increasing the incidence of urinary calculi. Other workers, including Beeson *et al.* (1943), and Watchorn (1932), indicate some relationship between magnesium content of the ration and the incidence of calculi. Johnson *et al.* (1940) were unable to produce calculi by feeding a ration, the dry matter of which contained 1.5 percent magnesium. Johnson *et al.* (1940) also state that an alkaline urine does not necessarily predispose to calculi formation.

Black *et al.* (1947) obtained an indication that urinary calculi in steers being fattened on grain sorghums may be controlled to a con-

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[2] Present address: Department of Animal Husbandry, Mississippi State College.

[3] Assistant Animal Husbandman, Graduate Assistant, Assistant Animal Husbandman, and Animal Husbandman, respectively.

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siderable extent by feeding threshed grain rather than the heads and by supplementing the ration with phosphorus. They also received a slight benefit from calcium supplementation. Newsom *et al.* (1943) state that a ration of cane fodder, bran, and white corn is more likely to produce calculi than alfalfa or beet tops and yellow corn. This ration was low in carotene, had a narrow Ca-P ratio, required little water intake, and resulted in a small urine output. The urine from sheep fed this ration was nearly neutral and was low in total solids and specific gravity.

Silica has received considerable attention as being involved in calculi formation. Beeson *et al.* (1943) reported the occurrence of a rare siliceous type of calculi that was attributed to a hyperexcretory state in which urinary magnesium played a role in establishing the urinary silica solubility limitations.

TABLE 1. FEED AND WATER ANALYSIS

Analysis	Calcium	Phosphorus	Magnesium
Feed (basal ration), percent	0.305	0.285	trace
Water, milligrams percent	5.80	0.74	2.23

Eveleth *et al.* (1948) take the position that no single entity is responsible for calculi formation but that it probably results from multiple causes.

The effects of various mineral supplements, water intake, pH, urine volume, urine total solids, and a low carotene diet on the formation of urinary calculi in ram lambs are presented in this paper.

Materials and Methods

Fifty-four cross bred (Hampshire×Rambouillet and Suffolk×Rambouillet) ram lambs were used in this study. The lambs were obtained from a commercial lamb producer at weaning time. They averaged approximately 105 pounds and varied from 82 to 129 pounds in weight when put on experiment a month later.

The basal ration was the same as that used by Lindley *et al.* (1949) except that it was pelleted. The calcium, phosphorus, and magnesium contents of the feed and water are given in table 1.

The rams were divided into nine lots of six rams each so that all lots were approximately equal in average initial weight. Twice each day the rams were fed individually as much of the ration as they would clean up. They were watered individually once daily, and the

amount of water that each consumed was measured. The specific treatment for each of the lots was:

(1)—Basal ration of wheat straw, 25 percent; dried beet pulp, 25 percent; linseed meal, 18 percent; oats, 17 percent; and wheat, 15 percent.
m—Basal ration plus $CaCO_3$ and $MgCO_3$.
p—Basal ration plus K_2HPO_4.
mp—Basal ration plus $CaCO_3$, $MgCO_3$ and K_2HPO_4.
a—Basal ration plus vitamin A.
am—Basal ration plus vitamin A, $CaCO_3$ and $MgCO_3$.
ap—Basal ration plus vitamin A and K_2HPO_4.
amp—Basal ration plus vitamin A, $CaCO_3$, $MgCO_3$ and K_2HPO_4.
(1)A—Alfalfa substituted for wheat straw in the basal ration.

The vitamin A was fed in the form of shark liver oil placed on the feed twice each week. The $CaCO_3$, $MgCO_3$ and K_2HPO_4 were fed at the rate of 3.5 gms., 3 gms., and 11 gms. per pound of feed, respectively. The mineral supplements were mixed with the feed before it was pelleted. The rams were weighed at 14-day intervals throughout the feeding period.

Blood calcium and magnesium were determined three times during the feeding period. Blood phosphorus was determined four times. Calcium was determined by a modification of the Roe and Kahn procedure (1926); the phosphorus by a modification of the method of Fiske and Subbarow (1925); and the magnesium by a modification of the method of Denis (1922). Urine volume per 24 hours, total solids, calcium, phosphorus and magnesium were measured four times during the 181 days the rams were on feed. The pH of fresh urine was determined six times during this period. The urine was collected by watering the rams and turning them out of the individual stalls immediately. Almost without exception the rams would urinate within a matter of a very few minutes. The urine for a 24-hour period was collected by use of a female urinal as described by Beeson *et al.* (1943). Calcium was determined by the method of Roe and Kahn (1926) adapted to urine analysis; phosphorus by a modification of Fiske and Subbarow (1925) adapted to urine analysis; magnesium by a modification of Denis (1922) adapted to urine analysis; and the pH with a Beckman Model H-2, pH meter.

When the rams showed symptoms of calculi, they were killed by electrocution and autopsied to determine the condition of the urinary

tract and to regain the stones. At this time blood and urine samples were taken for analysis, but the urine was contaminated with blood to such an extent that results of the analysis were considered valueless. Also the blood was so high in products from the urinary system that the blood analysis was of no value. All except eight of the rams were slaughtered at the end of the 181-day feeding period.

Figure 1. An acute case of urinary calculi of a ram receiving the basal ration plus $CaCO_3$, $MgCO_3$, and K_2HPO_4. Note the straining that was characteristic of all cases of urinary calculi.

Results and Discussion

General Symptoms of Urinary Calculi

The symptoms of urinary calculi developed rather suddenly. The first noticeable symptom was a drowsy attitude of the ram and a failure to eat or drink. Within a few hours after this, an acute case of urinary calculi had developed. Figure 1 shows a ram that received the basal ration plus $CaCO_3$, $MgCO_3$ and K_2HPO_4. This picture was taken just before he was autopsied with an acute case of urinary calculi. The symptom of the ram straining extremely hard to try

to urine is shown. Evidence of the pain caused by straining was shown by a characteristic curling of the upper lip. Some rams passed a small amount of urine and were able to withstand the condition better than those unable to pass any urine. Two rams passed the stones through the wall of the urinary tract and continued on feed for some time. At autopsy it was evident that the stones had been forced

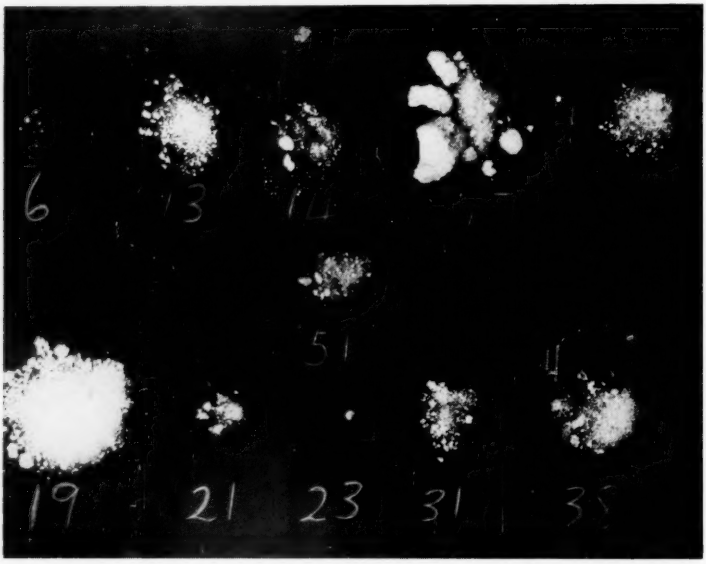

Figure 2. Stones removed from several rams. Note the extreme size in the stones from number 17. These were taken from one kidney. The larger stone was approximately 1 inch by 1.5 inches.

through the urethra and walls of the penis to allow urine to escape in this manner.

Extensive damage to the urinary system caused by the calculi was apparent at the time of autopsy. The kidneys were usually greatly dilated with many gray areas in the cortex extending in streaks down to the pelvis. The bladders were dilated with bloody urine. The mucosa of the bladders was usually thickened and dark red. There was a gelatinous material that covered the bladder in all cases. The kidneys, bladders, urethras, and urethral processes contained varying numbers and sizes of stones. Figure 2 shows stones from several

of the rams. The stones from Ram 17 were all taken from the kidney. Each kidney contained about this amount of stones. The large stone was approximately 1 x 1.5 inches.

Table 2 gives the number of cases of calculi produced by each treatment, the average number of days on trial before calculi were produced, and the means of the urine and blood constituents and water consumption for all lots except that receiving alfalfa hay instead of wheat straw.

Since there were eight cases of calculi from lots receiving no vitamin A and six cases (including the alfalfa lot) from lots receiving vitamin A, it was evident that a diet free of carotene or vitamin A was not involved in urinary calculi formation.

There were seven cases (including the alfalfa lot) in the lots receiving $CaCO_3$ and $MgCO_3$ and seven cases in the lots without these additions, so in this experiment calcium and magnesium cannot be considered as causative factors in the formation of calculi.

There were twelve cases of calculi produced when K_2HPO_4 was added to the ration and only two cases when it was not added. Therefore, these data indicate that phosphorus was a causative factor in the formation of calculi in sheep.

Daily Gain and Feed Efficiency

While the daily gain and feed efficiency seemingly had no bearing on calculi formation, they are of general interest. There was a significant difference between lots in daily gain with no difference in efficiency. Any differences were primarily between vitamin A-free lots and those receiving vitamin A. Since vitamin A deficiencies were just beginning to show up, great differences would not be expected in daily gain and feed efficiency.

To obtain the maximum efficiency from the data, a factorial analysis was applied. To analyze these data in this way, it was necessary to exclude the lot in which alfalfa was substituted for straw. However, on a previous analysis, this showed no significant effect on calculi formation. The treatment effects and interactions per ram for urine and blood constituents and water consumption are given in table 3.

Urine Analysis

The addition of phosphorus to the ration increased urine excretion very significantly ($P<.01$). No other factor had a significant effect on the amount of urine excreted. Likewise, the phosphorus supple-

TABLE 2. OCCURRENCE OF CALCULI, AND MEANS OF THE URINE AND BLOOD CONSTITUENTS AND WATER CONSUMPTION

	(1) Basal	m Basal+ $CaCO_3$+ $MgCO_3$	p Basal+ K_2HPO_4	mp Basal+ $CaCO_3$+ $MgCO_3$+ K_2HPO_4	a Basal+ Vitamin A	am Basal+ Vitamin A+ $CaCO_3$+ $MgCO_3$	ap Basal+ Vitamin A+ K_2HPO_4	amp Basal+ Vitamin A+ $CaCO_3$+ $MgCO_3$+ K_2HPO_4
No. rams having calculi during experiment [1]	1	0	3	4	0	0	2	3
Av. days on feed (rams having calculi)	101	....	144.3	94.0	....	....	135.5	141.7
Urine volume, ml.	745.2	764.0	1025.5	878.7	735.5	743.7	1033.8	864.5
Urine phosphorus, mg. %	6.61	2.79	37.89	41.11	2.06	1.69	26.25	8.78
Urine magnesium, mg. %	0.65	0.45	0.60	0.80	1.12	0.41	0.52	0.57
Urine calcium, mg. %	2.13	2.11	2.66	1.63	3.26	3.08	3.56	2.85
Urine gm. solid per 100 ml.	7.01	8.50	5.09	5.62	8.35	8.07	7.25	6.74
Urine total solid per 24-hour period, gm.	51.62	64.69	56.08	49.71	59.45	59.06	66.66	57.00
Urine pH	7.13	7.38	7.36	7.37	7.02	7.34	7.31	7.45
Blood phosphorus, mg. %	8.67	8.90	12.75	8.60	7.24	7.82	11.18	10.53
Blood magnesium, mg. %	0.12	0.22	0.17	0.18	0.18	0.29	0.18	0.23
Blood calcium, mg. %	9.26	9.10	7.40	9.08	7.68	9.53	6.89	8.28
Water consumption, l's. (14 days)	88.2	96.3	100.3	115.0	78.7	97.3	100.2	105.7

[1] There was one case of urinary calculi in the lot of lambs fed alfalfa hay, not included in this table.

mentation increased the amount of phosphorus in the urine, a difference that was highly significant.

When vitamin A was added to the ration, the urine phosphorus was reduced by a significant amount. Likewise, vitamin A supplementation increased the calcium excretion in the urine in a highly significant manner. Urine magnesium was not significantly influenced by any treatment.

TABLE 3. TREATMENT EFFECTS AND INTERACTIONS ON A PER ANIMAL BASIS FOR URINE, AND BLOOD CONSTITUENTS AND WATER CONSUMPTION

	M[1]	P[2]	MP	A[3]	AM	AP	AMP
Urine Volume, ml.	−71.8	204.0**	−9.4	−1.0	−7.9	2.3	3.4
Urine Phosphorus, mg. %	−4.6	25.2**	−2.5	−12.4	−4.3	−9.6	6.0
Urine Magnesium, mg. %	0.16	0.03	0.28	0.03	−0.16	−0.16	0.1
Urine Calcium, mg. %	−0.44	−0.01	−0.34	1.01**	−0.08	−0.04	0.16
Urine gm. Solid per 100 ml.	0.31	−1.80**	−0.30	1.05*	−0.70	0.59	0.18
Urine Total Solids per 24-hour period, gm	−0.84	−1.34	−7.17	5.00	−4.18	3.92	2.56
Urine pH	0.181**	0.157**	−0.104**	−0.032*	0.05**	0.05**	0.18**
Blood Phosphorus, mg. %	−1.00*	2.63**	−1.40**	−0.53	−0.96*	0.69	0.79
Blood Magnesium, mg. %	0.07	−0.01	−0.04	0.05	0.01	−0.02	0.007
Blood Calcium, mg. %	1.32*	−0.86	0.47	−0.74	0.30	0.17	0.70
Water Consumption, lbs.	8.38	11.59	−5.04	−1.12	3.71	3.12	−1.54

[1] M = Average effect of adding $CaCO_3$ + $MgCO_3$.
[2] P = Average effect of adding K_2HPO_4.
[3] A = Average effect of adding vitamin A.
* $P < 0.05$.
** $P < 0.01$.

There were fewer solids per 100 ml. of urine from the ram lambs fed phosphorus than from those receiving any other mineral supplements or combinations of supplements. This was highly significant and indicates that phosphorus supplementation had tied up other minerals as insoluble phosphates.

The results of the analysis of the urine pH values must be viewed with caution. In this case all effects and interactions appear to be significant, yet no very large differences in pH were encountered. This may have arisen as a result of an unusually low level of variation, yet observation suggested that the trend would be more in the opposite direction; the rapid change in pH from the moment of excretion casts some reflection on the accuracy of these values. That there

was no apparent association between occurrence of calculi and differences in pH seems to substantiate this view. Johnson *et al.* (1940) have shown that pH of the urine does not predispose to calculi formation.

Blood Analysis

When phosphorus was the only mineral supplement, the increase in the phosphorus content of the blood was highly significant. If calcium and magnesium were both added to the ration, the blood phosphorus was significantly lower than when phosphorus was the only supplement. Also when calcium, magnesium and phosphorus were

TABLE 4. CALCIUM, PHOSPHORUS, MAGNESIUM, AND ORGANIC MATTER CONTENT OF THE CALCULI REMOVED FROM URINARY TRACTS

Ram No.	Calcium (Mg. per gm.)	Phosphorus (Mg. per gm.)	Magnesium (Mg. per gm.)	Organic Matter (percent)
13	180.85	101.03	70.92	....
14	138.12	172.56	62.79	....
17	150.51	89.73	76.34	50.1
18	148.32	85.97	73.88	....
19	125.16	74.67	92.84	38.3
21	213.62	85.97	71.91	....
31	146.14	82.20	91.36	....
37	230.86	143.07	270.88	....
38	211.19	115.46	120.17	34.8
51	109.24	89.73	112.29	....

added to the basal ration, the blood phosphorus was significantly less than when phosphorus was fed alone. This indicated a direct relationship between the calcium-phosphorus ratio of the feed and the phosphorus content of the blood.

Blood magnesium was not significantly affected by any treatment. However, the blood calcium was significantly greater in lots in which calcium and magnesium were fed than in other lots.

Calculi Analysis

The analyses of the calculi are given in table 4. If the phosphorus is considered as phosphate and added to the calcium, magnesium and organic matter of the calculi, almost 100 percent of the calculi is accounted for. It is assumed, then, from this and from the analysis of the blood and urine, that the phosphorus tied up the calcium

and magnesium as insoluble phosphates. If it were assumed that these occurred as $Ca_3(PO_4)_2$, $Mg_3(PO_4)_2$ and $MgNH_4PO_4$, it would be consistent with the amounts of the elements found. These compounds would be insoluble in the urine and would settle out with a high retention rate and calculi formation.

Summary

Data on the effect of high intake of $CaCO_3$, $MgCO_3$ and K_2HPO_4 on the blood and urine contents of calcium, phosphorus, magnesium, urine pH, urine total solids, urine volume and their possible relation to urinary calculi formation have been presented. Under the conditions of this experiment, supplementation with K_2HPO_4 was apparently the cause of the highest incidence of calculi. A vitamin A- or carotene-free diet does not seem to be involved in calculi formation. The rams that produced urine with the lowest total solids were the rams that had the highest incidence of calculi. In the lots where there was a high incidence of calculi, the rams had an increased rate of water consumption and an increased rate of urine excretion.

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CAROTENE AND VITAMIN A METABOLISM IN CATTLE AND SHEEP ON PHOSPHORUS-DEFICIENT RATIONS

WILLIS D. GALLUP, O. O. THOMAS, O. BURR ROSS and C. K. WHITEHAIR

Oklahoma Agricultural Experiment Station[1]

IN studies of the effect of phosphorus deficiency on carotene and vitamin A metabolism, increases in plasma carotene levels were observed in separate experiments with phosphorus-deficient steers (Thomas, Gallup and Ross, 1951) and beef cows (Thomas, Gallup and Whitehair, 1953). Although these increases were relatively small, they were believed to indicate inefficient conversion of carotene to vitamin A during phosphorus deficiency. Studies with sheep failed to support such a conclusion. The experiments with steers and sheep, which have been briefly reported elsewhere (Thomas *et al.*, 1951), are described in the present paper.

Experimental

The general plan in these experiments was to feed a constant amount of carotene and a low and high level of phosphorus to animals that had been depleted in phosphorus and vitamin A reserves.

Steers

Nine yearling Hereford steers that had been grazing the same pasture during the summer were put in dry lot and fed a low-phosphorus wintering ration of prairie hay free choice, 2 lb. of corn gluten meal and salt. At monthly intervals, blood samples were taken for the determination of plasma carotene, vitamin A and inorganic phosphorus. After 117 days, plasma phosphorus values were still high; consequently, the protein supplement was decreased to 1 lb. so that the ration now supplied less than 1 gm. of phosphorus per 100 lb. bodyweight. The hay at this time contained 17 p.p.m. of carotene. At 280 days, when it became evident that the steers were reaching a phosphorus depletion stage and that their vitamin A reserves were low, they were divided into two groups and placed in stalls for individual feeding. Four of the steers constituting lot 1 were continued on the phosphorus-deficient ration of 10 lb. of hay, containing less

[1] Departments of Agricultural Chemistry Research and Animal Husbandry.

than 10 p.p.m. of carotene, 1 lb. of corn gluten meal, salt and 65 gm. of calcium carbonate. The ration provided a daily intake of 6.4 gm. of calcium and 0.50 gm. of phosphorus per 100 lb. body weight. The remaining five steers constituting lot 2 were fed the same ration with the calcium carbonate replaced by 100 gm. of dicalcium phosphate. The ration supplied 3 gm. of phosphorus per 100 lb. body weight and the same amount of calcium as for lot 1. Carotene intake was kept the same for the steers in both lots; it was increased 60 days after allotment from about 13.8 mg. per steer per day to 150 mg. by the daily addition of a carotene concentrate to the ration. From the time phosphorus supplementation was started for lot 2 until the animals were slaughtered at the end of the experiment, blood samples were taken approximately every 10 days and liver samples were taken by biopsy at three 4-week intervals (Whitehair, Peterson, Van Arsdell and Thomas, 1952). Whole livers were secured for analysis at the time of slaughter. Liver samples were wrapped in cellophane and kept frozen until analyses could be made the following day.

Lambs

A group of 9 lambs with an average initial weight of 55 lbs. were depleted in phosphorus and vitamin A by feeding a daily ration of 1 lb. of cottonseed hulls, 0.45 lb. of a mixture of equal parts corn gluten meal, starch and sucrose, and 5 gm. of salt. The lambs were kept inside and at 192 days, 2 gm. of calcium carbonate and a vitamin D supplement which supplied five times minimum requirements were added to their ration. The mixed concentrate feed was later increased to 0.6 lb. and calcium carbonate was increased to 5 gm. Because of low plasma vitamin A values, carotene supplementation was started at 192 days. Every other day thereafter each lamb was given by capsule 5 ml. of a carotene concentrate prepared from alfalfa. Each capsule contained 13.6 mg. of carotene.

At 268 days the seven lambs that had survived this phosphorus depletion period were divided into two lots. The three lambs in lot 1 were continued on the low-phosphorus ration which supplied approximately 4 gm. of calcium and 0.85 gm. of phosphorus per 100 lb. body weight. The same ration supplemented with 8 gm. of dicalcium phosphate, by replacement of calcium carbonate, supplied the lambs of lot 2 with 4.4 gm. of calcium and 3.3 gm. of phosphorus on the same basis. Blood samples were taken at 10-day intervals for the determination of phosphorus and vitamin A, and at the end of 32 days

the lambs were slaughtered. Liver and bone samples were obtained at slaughter.

Reference to methods of chemical analyses are given in a previous paper (Thomas, Gallup and Whitehair, 1953).

Results and Discussion

Steers

The average weight of the steers was 679 lb. at the beginning of the experiment, 672 lb. at the end of the phosphorus depletion period and 717 and 760 lb. for lots 1 and 2, respectively, at the end of the experiment. The steers in lot 1, and those in lot 2 during depletion, showed typical symptoms of mild phosphorus deficiency. As shown in table 1, average plasma phosphorus values were 4.0 mg. percent for both lots at the end of depletion. They remained low for lot 1, but increased to as much as 12 mg. and remained over 7 mg. for lot 2 throughout the rest of the experiment.

Plasma carotene which was initially over 300 mcg. per 100 ml. decreased during depletion to levels of 98 mcg. for lot 1 and 115 mcg. for lot 2. After phosphorus supplementation was started for lot 2, differences in these values between lots became less. At 339 days, just before carotene intake was increased, the average values were 49 and 43 mcg. for lots 1 and 2, respectively. At every bleeding date thereafter, plasma carotene was higher in the phosphorus-deficient steers than in those fed adequate phosphorus, and at the end of the experiment the average values for the two lots were 119 and 76 mcg., respectively. Vitamin A values, however, showed an opposite trend in relation to phosphorus deficiency. The average value, which had decreased in both lots to 13 mcg. at the time carotene was added to the ration, was usually about the same or slightly lower in lot 1 than lot 2 during the early part of the phosphorus supplementation period. Toward the end of the experiment, differences became greater and in favor of lot 2. On the final bleeding date, average plasma vitamin A was 17 mcg. for the phosphorus-deficient steers and 22 mcg. for those fed adequate phosphorus.

The carotene content of liver samples taken during the experiment did not reveal marked differences between lots, nor consistent change other than a general increase after carotene intake was increased. In the limited number of samples available, this increase appeared to be greater for lot 1 than for lot 2. At the end of the experiment, livers from the steers of lot 1 weighed an average of 5.9 lb. and contained

TABLE 1. PHOSPHORUS, CAROTENE AND VITAMIN A CHANGES IN STEERS FED LOW-PHOSPHORUS (LOT 1) AND ADEQUATE-PHOSPHORUS (LOT 2) RATIONS AND EQUAL AMOUNTS OF CAROTENE

Experimental Days, and Treatment [1]		Plasma Phosphorus (mg./100 ml.)		Plasma Carotene (mcg./100 ml.)		Plasma Vitamin A (mcg./100 ml.)		Liver Carotene (mcg./100 gm.)		Liver Vitamin A [2] (mcg./100 gm.)	
		Lot		Lot		Lot		Lot		Lot	
		1	2	1	2	1	2	1	2	1	2
0	Initial	6.0		364		29		...	...	...	...
280	Allotment	4.0	4.0	98	115	16	20	225	158	938	950
318	Phosphorus supplementation	5.6	12.3	66	75	16	17	...	...	...	...
329	Phosphorus supplementation	5.0	9.3	54	55	17	16	...	...	...	...
339	Phosphorus supplementation	5.2	10.3	49	43	13	13	121	152	615	1237
353	Carotene supplementation	4.5	9.3	84	72	13	14	...	...	...	...
363	Carotene supplementation	4.8	9.3	108	80	15	16	196	179	840	1470
372	Carotene supplementation	4.6	8.4	90	76	12	18	...	...	...	...
384	Carotene supplementation	5.5	7.9	102	90	12	20	...	...	...	...
393	Carotene supplementation	4.5	7.7	108	80	17	23	165	171	639	1421
405	Slaughter	4.3	7.2	119	76	17	22	201	192	1786	1804

[1] At 309 days phosphorus intake for lot 2 was increased from 0.5 gm. per 100 lb. body weight to 3.0 gm., and at 340 days the steers in both lots were given a daily supplement of 136 mg. of carotene.

[2] Average total vitamin A content of the liver at slaughter was 46.8 mg. for lot 1 and 50.8 mg. for lot 2.

5.9 mg. of carotene; those from lot 2 weighed 6.2 lb. and contained 5.4 mg. Liver vitamin A values were consistently lower in the biopsy samples than in samples taken at slaughter. These lower results, ascribed to sampling difficulties in early application of the biopsy procedure, may be of relative importance but cannot be considered as representing absolute values. With this qualification in mind, it can be stated that: (a) At the time of phosphorus supplementation for lot 2, vitamin A reserves in the liver were about equal in the two lots; and that (b) after carotene intake was increased, storage of vitamin A increased and remained high in lot 2 as compared to lot 1. At the end of the experiment the phosphorus-deficient steers had an average of 46.8 mg. of vitamin A in their liver and those fed adequate phosphorus had 50.8 mg.

Although the results with steers invite speculation, their further interpretation would not be appropriate without confirmation with larger numbers. With respect to carotene changes in the blood plasma, the results are consistent with those obtained with beef cows (Thomas *et al.*, 1953).

Lambs

Although the lambs maintained their weight during the long phosphorus depletion period, they were in poor condition and possibly in a phosphorus deficient state before it was indicated by plasma values. The two lambs that died had plasma phosphorus values between 6 and 7 mg. percent a few days before death. Their femur bones taken at autopsy were small and thin-walled. Average plasma phosphorus of the other seven lambs at the time phosphorus supplementation was started for lot 2 was about 5 mg. It decreased to 3.4 mg. in the lambs of lot 1 and increased in those of lot 2 to 7.6 mg. during the subsequent and final 30-day period. Femur bone samples obtained from the lambs of lots 1 and 2 at the end of the experiment contained an average of 66.8 and 67.9 percent ash (dry fat-free basis), respectively.

Plasma vitamin A decreased during phosphorus depletion from an average initial value of 28 mcg. to about 3 mcg. at 192 days. Carotene intake was increased at this time, and when phosphorus supplementation was started at 268 days the average vitamin A values for lots 1 and 2 were 14.3 and 15.1 mcg., respectively. From that time on, average plasma vitamin A levels were consistently higher for the phosphorus-deficient lambs than for those fed adequate amounts. On

the last day of the experiment the individual values were 20.0, 20.3 and 20.8 mcg. for lot 1, and 15.1, 15.3, 19.2 and 23.0 mcg. for lot 2. Vitamin A reserves in the liver were likewise higher in the phosphorus-deficient lambs, the individual values in mcg. per gm. (fresh basis) for lambs in the same order as given above being 12.0, 15.7 and 12.0 for lot 1, and 15.2, 10.3, 10.8 and 10.8 for lot 2.

TABLE 2 PHOSPHORUS, CAROTENE AND VITAMIN A CHANGES IN LAMBS FED LOW-PHOSPHORUS (LOT 1) AND ADEQUATE-PHOSPHORUS (LOT 2) RATIONS AND EQUAL AMOUNTS OF CAROTENE

Experimental days, and treatment[1]	Plasma Phosphorus (mg./100 ml.)		Plasma Vitamin A (mcg./100 ml.)		Liver Vitamin A (mcg./gm.)		Femur Bone Ash[2] (%)	
	Lot		Lot		Lot		Lot	
	1	2	1	2	1	2	1	2
0 Initial	5.5		27.8		....	....	....	....
192 Carotene Supplementation	7.8	8.6	2.8	4.3	....	....	....	....
268 Phosphorus Supplementation	5.0	5.0	14.3	15.1	....	....	....	....
281 " "	3.1	6.8	23.8	18.9	....	....	....	....
290 " "	2.8	6.8	23.8	20.4	....	....	....	....
299 " "	3.4	7.6	20.4	18.2	13.2	11.8	66.8	67.9

[1] At 192 days the lambs in both lots were given a supplement of 13.6 mg. of carotene every other day, and at 268 days the phosphorus intake for lot 2 was increased from 0.85 gm. per 100 lb. body weight to 3 gm.
[2] Dry, fat-free basis.

These results, obviously, do not lend support to the idea that phosphorus deficiency, at least in lambs, interferes with the normal conversion of carotene to vitamin A. On the contrary, the data tend to supply evidence of a contradictory nature. The results are in general agreement with the report by Klosterman and associates (1952) of a highly significant negative correlation between plasma inorganic phosphorus and vitamin A in lambs fed low- and adequate-phosphorus rations deficient in carotene. These investigators also found that, in rats given equal amounts of carotene or vitamin A, liver stores of vitamin A were greater in the animals fed low-phosphorus than in those fed high-phosphorus rations.

In sheep, as in the rat, the metabolism of carotene is characterized by efficient conversion to vitamin A. Extremely small or negligible amounts of carotene appear in the blood, liver, and other tissues. In cattle on natural rations, carotene is normally present in the blood in an amount that is characteristic of the breed, and for any one breed, is proportional to intake. In view of this difference between sheep and cattle in the metabolism of carotene, a difference in their

vitamin A response to phosphorus deficiency, although speculative, appears reasonable.

Summary

Nine yearling steers, after depletion in phosphorus and vitamin A reserves, were given daily supplements of carotene equivalent to about 10 times their minimum requirement. Four of the steers were continued on the low-phosphorus ration and five which served as controls were given supplemental phosphorus. In confirmation of other work with cows, plasma carotene levels were consistently higher in the steers on the low-phosphorus ration. The average value at the end of the experiment was 119 mcg. percent for the low-phosphorus group and 76 mcg. for the controls. Plasma vitamin A values for these two groups were 17 and 22 mcg. percent, respectively. Decreased vitamin A storage in the liver of the phosphorus-deficient steers was indicated.

Results obtained with lambs in a similar experiment showed a different trend than that noted with cattle. The average vitamin A content of the plasma in the phosphorus-deficient lambs was 20.4 mcg. percent as compared to 18.2 mcg. in the controls. Also, vitamin A stores in the liver were greater in the phosphorus-deficient lambs, 13.2 mcg. per gram (fresh basis), than in the controls, 11.8 mcg. On the basis of available data, it seems a plausible suggestion that a species difference exists in the vitamin A response of cattle and sheep to phosphorus deficiency.

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DIGESTIBILITY AND CONSUMPTION OF PASTURE FORAGE BY GRAZING SHEEP [1]

BURCH H. SCHNEIDER, BALBIR K. SONI and WENDELL E. HAM
State College of Washington

IN the increasingly important search for non-human food as a source of nutrients for livestock production, grassland is being recognized more and more in all parts of the world. For the proper evaluation of pasture production, it is necessary to estimate the nutritive value and the amount of forage available. The absence of reliable and easy methods of determining the amount and digestibility of forage consumed by grazing animals has been one of the greatest deterrents in such investigations.

Since the animals select certain plant species and similarly show preference for particular portions of various plants, it becomes difficult, if not impossible, to obtain a representative sample of the forage actually eaten. To overcome this problem, various indirect methods have been proposed. Raymond (1948) and Gallup and Briggs (1948) showed that there was a definite relationship between fecal nitrogen, forage nitrogen, and digestibility of dry matter. Lancaster (1949a, b) and Homb and Breirem (1952) suggested different constants for the determination of digestibility and consumption of forage from the fecal nitrogen excretion. Forbes (1949) could not find any significant relationship between the nitrogen excreted in the feces and the protein content of forage and thus suggested the use of forage protein and an indigestible tracer such as lignin for these purposes. Reid *et al.* (1950) described the use of naturally-occurring chromogens—indigestible pigments in the plant—as a reference material. Later Reid *et al.* (1952) established a mathematical relationship between the chromogen-dry matter ratio of the feces voided and that of the forage consumed. "This relationship allowed the circumvention of the manual sampling of forage as it was found that the chromogen concentration of the forage could be predicted from the knowledge of fecal chromogen level." Except for Cook and Harris (1951), who worked with range plants having a very high percentage of ether extract, several investi-

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gators have reported satisfactory and reliable results by the use of this method (Kane *et al.*, 1951; McCullough *et al.*, 1951; Hardison *et al.*, 1951; and Richards and Reid, 1952).

Because there was not enough information available in the literature about the digestibility and consumption of pasture forage by grazing sheep, this experiment was planned to obtain this information, using chromogen and fecal nitrogen as indicators.

Experimental

Nine male sheep—three adult rams, three yearlings and three lambs, weighing approximately 200 pounds, 150 pounds and 70 pounds respectively—were used. One acre of permanent pasture containing predominately Orchardgrass *(Dactylis glomerata)* with some cheatgrass brome *(Bromus tectorum)* was fenced and divided into two parts—⅔ in one part and the remaining ⅓ in the other. Adequate shelter, drinking water, and salt were available to the animals at all times. With the idea of determining the seasonal changes in digestibility and consumption, three stages of maturity were studied. In the bloom stage, the orchardgrass was about one and one-half to two feet in height, being "one-half headed" to "full headed." In the seed stage, the grass was in an advanced stage of maturity and all heads had formed seed. The second-cutting stage was regrown grass about six inches high obtained after mowing the grass in bloom stage.

When the experiment was started, the animals were put in the ⅔-acre part of the pasture and studies were made first of the bloom stage. When the grass in the ⅓-acre lot had reached the seed stage, the animals were moved in and the material collected for seed stage of maturity. To obtain the second cutting stage, the ⅔ part of the pasture was mowed at the close of the bloom stage studies and allowed to regrow. The sheep were put in this pasture when the new grass was about six inches high and the series of experiments thus completed.

For each stage, the preliminary period consisted of ten days and the collection period of four days, except in the second-cutting stage. In the latter the regrown grass was not enough, so only a five-day preliminary period was used. The short collection period, similar to that used by Reid *et al.* (1952), was so planned as to minimize the effect of changing forage composition. To overcome the "lag" in forage consumption and its appearance as feces, the sampling of forage was started two days before the fecal collection period and

continued for four days. About one and one-half to two hours were spent daily in walking along among the sheep while they were grazing so as to pluck the portion of the plant they were observed to consume. In spite of this, it was not possible to be sure that the samples plucked were truly representative of the forage ingested by the sheep. Total collection of feces was made by the use of a harness and feces sacks specially designed for sheep similar to those used by Garrigus and Rusk (1939) for steers. The feces were collected and weighed once daily during the collection period. At the end a composite of each animal's feces was made.

The forage consumption also was estimated by the clipping method. For this purpose, at the beginning of the preliminary periods and at the end of collection periods in the bloom and the seed stage, nine strips 12 feet x 3 feet, randomly selected, were mowed with a power mower. The forage available at these times was thus estimated for the entire pasture lot. The difference between the estimates at the beginning and the end gave one measure of the forage consumed by the animals. In the second-cutting stage there was not enough grass, so to economize on the green grass at the beginning of the collection period, nine random samples of forage were taken by throwing an iron ring three feet in radius at nine different places and cutting the grass within the ring with a hand sickle. At the end of the collection period for the second-cutting stage, it was noted that there was not any grass left which could be removed by hand sickle or power mower. Thus, it was concluded that in this stage all of the forage available had been consumed by the animals.

For chemical analysis of forage and feces, the methods of the Association of Official Agricultural Chemists (1945) and for chromogen the method of Reid *et al.* (1952) were followed. The heat of combustion was determined on forage and feces with a bomb calorimeter.

Results and Discussion

The chemical analyses of forages showed that the dry matter and crude fiber content of the forage was higher in the later stages. The ether extract decreased appreciably from bloom stage to seed stage and to second cutting stage. Protein was lowest (7.7 percent) in seed stage and approximately the same (9.9 percent) in the other two stages. The crude protein and ether extract content of the feces decreased, while the nitrogen-free extract increased, with the advancing age of the plants consumed.

The digestion coefficients as determined by the chromogen technique (Reid *et al.*, 1952) are given in table 1. The mean apparent digesti-

TABLE 1. DIGESTION COEFFICIENTS AS DETERMINED BY CHROMOGEN TECHNIQUE

Animal	Dry Matter	Crude Protein	Ether Extract	Nitrogen-Free Extract	Crude Fiber	Energy
			Bloom Stage			
Adult rams	71.8[1]	71.1	38.2	80.6	73.0	71.2
	62.6	57.1	24.0	75.9	69.2	63.5
	64.0	56.7	23.5	73.5	69.8	63.4
Yearlings	66.6	57.1	24.4	77.9	73.0	65.7
	59.0	57.7	34.2	70.5	60.6	59.0
	58.4	58.0	39.7	70.8	58.7	58.2
Lambs	67.2	45.3	37.7	82.6	73.3	66.9
	65.0	56.5	37.4	78.2	69.6	68.4
	65.5	51.6	28.3	76.7	73.6	65.0
Averages	64.4	56.8	31.9	76.3	69.0	64.6
			Seed Stage			
Adult rams	58.1	54.4	42.3	69.0	64.8	60.5
	57.7	37.2	14.4	68.0	74.5	59.1
	58.0	42.2	14.2	63.4	71.6	59.3
Yearlings	53.9	40.3	11.3	63.0	64.2	53.2
	70.7	64.7	68.5	74.5	74.1	73.0
	53.3	49.4	23.8	61.2	62.0	53.6
Lambs	57.3	49.8	10.2	66.7	62.9	55.7
	53.9	41.4	12.6	67.6	61.7	53.2
	55.4	47.7	11.3	67.6	58.6	53.0
Averages	57.6	47.4	23.2	66.7	66.0	57.8
			Second Cutting Stage			
Adult rams	58.0	63.8	34.4	66.1	62.4	60.3
	54.5	50.8	15.0	67.9	74.0	58.2
	53.5	51.8	12.1	69.2	72.1	58.5
Yearlings	52.9	59.3	8.4	64.5	62.7	54.4
	74.0	76.5	63.1	78.6	76.0	74.8
	53.6	61.6	12.4	64.4	62.0	56.6
Lambs	52.9	58.7	9.8	65.5	58.9	53.4
	53.1	51.4	14.6	64.2	61.7	56.2
	53.2	58.4	17.7	65.1	63.2	56.5
Averages	56.2	59.1	20.8	67.3	65.9	58.8

[1] Each figure is the coefficient for one individual ram.

bilities of dry matter for three stages of maturity were: bloom stage 64.4 ± 3.2,[2] seed stage 57.6 ± 4.1,[2] and second-cutting stage 56.2 ± 5.3.[2] It was noted that one of the yearlings had exceptionally high digestion coefficients for dry matter in the seed and the second-cutting stages. If the results with this animal are excluded, the average digestion coefficients of the other eight animals are 55.9 ± 1.7,[2] and 54.0 ± 1.4,[2] respectively, for these two stages. The analysis of variance on the digestibility of dry matter revealed highly significant differences due to the difference in stages of maturity of the plants. However, no difference in digestibility was shown due to difference in age of the sheep. The interaction between stage of maturity of the grass and age of the animals was also non-significant, indicating that all of the three age groups of sheep were equally efficient in digestion during all three stages of maturity of the forage.

When the coefficients of dry matter digestibility were determined by using fecal nitrogen as suggested by Lancaster (1949a), the averages were 66.9, 57.0 and 57.7 for bloom, seed, and second-cutting stages, respectively. These values are very similar to those obtained with the chromogen technique.

In order to examine various relationships, correlation coefficients were determined between different chemical moieties of both the forages and feces and dry matter digestibility of the forages estimated by the chromogen technique. The correlation coefficients of forage constituents, although statistically non-significant (Snedecor, 1946), indicated that as the level of crude fiber increased, the content of crude protein and digestibility of dry matter decreased. In considering the fecal constituents, it was found that there was a significant correlation similar to that obtained by Richards and Reid (1952) between the crude protein content of feces and the digestible dry matter in the forage. No correlation was found between the protein content of the forage and the digestion coefficient of its dry matter. This would suggest that the nitrogen content of feces as suggested by Lancaster (1949a) is a better indicator of digestibility than the forage protein method of Forbes (1950).

The consumption of forage as determined by the chromogen technique is shown in table 2. When the dry matter consumption was expressed as pounds per 100 pounds of body weight, it was noted that the adult animals consumed much less on this basis than the younger ones. The average daily dry matter consumption was found

[2] Fiducial limits $= t_{0.05} \times$ standard error of the mean.

TABLE 2. AVERAGE DAILY FORAGE CONSUMPTION ON FRESH WEIGHT AND DRY MATTER BASES AS DETERMINED BY THE CHROMOGEN TECHNIQUE

Bloom Stage		Seed Stage		Second-Cutting Stage	
Dry Matter Basis	Fresh Weight Basis	Dry Matter Basis	Fresh Weight Basis	Dry Matter Basis	Fresh Weight Basis
gm.	gm.	gm.	gm.	gm.	gm.
		Adult Rams			
2121[1]	7809	1032	2243	854	1960
844	3107	322	699	304	698
1043	3840	242	526	403	924
		Yearlings			
1256	4624	898	1950	1219	2797
1132	4167	1520	3300	1637	3756
604	2223	671	1457	996	2285
		Lambs			
308	1134	836	1815	734	1684
675	2485	742	1611	761	1762
450	1656	696	1511	989	2269
		Totals			
8433	31,045	6959	15,112	7897	18,135

[1] Each figure is the estimated consumption for one individual ram.

to be 0.8, 1.7 and 2.2 pounds per 100 pounds of body weight for adult rams, yearlings and lambs, respectively.

In addition to the chromogen, the nitrogen, and the clipping methods, consumption of dry matter was also determined by the total digestible nutrient requirement method of Knott *et al.* (1934), which was developed with dairy cattle. The results from these methods are given in

TABLE 3. COMPARISON OF ESTIMATES OF MOISTURE-FREE FORAGE CONSUMPTION OF THE NINE SHEEP PER DAY

Stage of Forage Maturity	Chromogen Technique (Reid *et al.*, 1952)	Fecal Nitrogen		T.D.N. Requirement Method (Knott *et al.*, 1934)	Clipping Method
		(Lancaster, 1949)	(Gallup and Briggs, 1948)		
	gm.	gm.	gm.	gm.	gm.
Bloom	8433	9255	8125	113	11,451
Seed	6959	5492	6441	10.328	4983
Second-cutting	7897	5728	6679	7873	17,214

table 3. It may be noted that while the fecal nitrogen as an indicator gave results comparable to the chromogen method, the T.D.N. requirement method gave most variable results. This could be due to cattle-sheep species differences or to the inherent variability when a small number of animals is used.

Although it is recognized that it is difficult or impossible to sample exactly the same forage consumed by animals, an attempt was made to do this as closely as possible. It may be pointed out that the

TABLE 4. COMPARISON OF ESTIMATES OF TOTAL DIGESTIBLE NUTRIENTS (MOISTURE-FREE BASIS) OF FORAGES IN DIFFERENT STAGES OF MATURITY

Stage of Forage Maturity	Chromogen Technique (Reid *et al.*, 1952)	Fecal Nitrogen (Gallup and Briggs, 1948)	Digestible Energy (Lofgreen, 1951)	Mathematical Equations (Schneider *et al.*, 1952)	Mathematical Equations (Schneider *et al.*, 1951)
Bloom	64.36	74.06	60.72	66.64	63.50
Seed	57.41	65.73	53.75	66.52	61.20
Second-cutting	56.96	74.55	53.51	65.58	62.10

digestion coefficients given in table 1 were calculated by using the values of chromogen for each animal obtained from the equations of Reid *et al.* (1952), in the following formula:

$$\text{Digestibility} = 100 - 100 \frac{\dfrac{\text{Percent of indicator in feed}}{\text{Percent of indicator in feces}} \times \dfrac{\text{Percent of nutrient in feces}}{\text{Percent of nutrient in feed}}}{}$$

In this method the amounts of chromogen in the forage eaten by different animals are considered to be different and the percentages of different nutrients are assumed to be the same. This latter assumption may not be correct because the change in the chromogen content of ingested forage indicates that there may also be a corresponding change in the content of other chemical entities (nutrients).

The total digestible nutrients calculated by different methods are given in table 4. The values obtained through the use of the nitrogen content of the feces as the indicator appear to be too high. The regression equations suggested by Schneider *et al.* (1951, 1952) gave com-

parable values for the bloom stage, but such mathematical estimates do not show the same degree of decrease in T.D.N. values associated with advance in maturity as shown by those estimated by the indicator methods. Possibly the reason for this is that the original digestion experiments from which the data for these regression equations were taken did not include samples from all of these stages or at least samples equally weighted between them. When the method of Lofgreen (1951) was used to calculate the total digestible nutrients, the values obtained were lower than those determined by the chromogen experimental method.

Summary

The digestibility and consumption of pasture forage by grazing sheep of three age groups are presented. The age of sheep did not affect their digestion, but the advance in stage of maturity of the grass resulted in a significant decrease in digestibility.

The average digestibility of dry matter by the chromogen method was 64.4, 57.6 and 56.2 for the bloom, seed, and second-cutting stages, respectively.

The daily average dry matter consumption was 0.8, 1.7 and 2.2 pounds per 100 pounds body weight for the adult rams, yearlings, and lambs, respectively.

When digestibility and consumption as determined by the chromogen method were compared with other available methods, the nitrogen content of feces method suggested by Lancaster (1949 a) gave comparable results. The percent digestible energy as proposed by Lofgreen (1951) gave lower values of T.D.N.—61, 54, and 54—as compared with 64, 57, and 57 by the chromogen technique, for the bloom, seed, and second-cutting stages of pasture forage maturity.

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OBSERVATIONS UPON AN UNIDENTIFIED FACTOR IN FEEDSTUFFS STIMULATORY TO CELLULOSE DIGESTION IN THE RUMEN AND IMPROVED LIVEWEIGHT GAINS IN LAMBS[1]

E. W. Ruf,[2] W. H. Hale and Wise Burroughs

Iowa Agricultural Experiment Station

THE efficiency with which cellulose is utilized in roughages fed to cattle and sheep is primarily dependent upon the degree of lignification in plant tissues (Crampton and Maynard, 1938) and the favorableness of conditions within the rumen for efficient cellulose digestion. Favorable rumen conditions have been shown (Burroughts *et al.*, 1951) to include specific nutrients: (1) energy, (2) available nitrogen, and (3) minerals reguired by rumen microorganisms. In addition to these specific nutrient requirements, attention has been called to the fact that certain feedstuffs and certain other materials such as manure extract contribute additional factors, presumably unidentified bacterial nutrients, helpful to improved fermentation within the rumen (Burroughs *et al.*, 1949, 1950a, b, c). Hungate (1950) and Doetsch *et al.* (1952) in pure culture investigations also demonstrated a need for materials of an unknown nature for optimal growth of rumen bacteria.

The purpose of this paper is to present further evidence that certain feedstuffs contain this unidentified factor and to determine some of its chemical and physical properties as well as demonstrate its significance upon liveweight gains when placed in the ration of lambs. The factor under study may well be of a multiple nature but for convenience will be referred to in this paper as a single component.

Experimental Procedure

The *in vitro* technique (artificial rumen similar to that described by Arias *et al.*, 1951) was employed in demonstrating the presence or absence of the factor in feedstuffs or feed fractions. In determining the influence of the factor on growth or liveweight gains in lambs, a semi-purified ration was used to which the factor was added as a yeast supplement.

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[2] The major part of this paper was taken from a thesis submitted by E. W. Ruf to the Graduate School of Iowa State College in partial fulfillment of the requirements of the degree of Doctor of Philosophy in Animal Nutrition, December, 1952.

The artificial rumen procedure included the carrying out of a series of 10 consecutive 24-hour fermentations. To the flasks was added daily a defined basal medium: 4.5 gm. Solka-floc (wood cellulose), 300 mg. urea, 0.5 gm. glucose, distilled water, and 35 ml. of a mineral solution as prepared by Burroughs *et al.* (1950b). Various feedstuffs or fractions were tested for the presence of the unidentified factor by adding them to flasks containing the basal medium and observing their stimulating effect upon cellulose digestion over that occurring where the test material was absent.

At the end of each 24-hour fermentation period, the contents of each flask (450 ml.) were divided into two equal portions. One portion (225 ml.) constituted the inoculum for the next 24-hour period and the other was used for analysis. In this way the nutrients of an unknown nature, incidentally brought into the fermentation via the inoculum obtained from the animal, were progressively diluted out. The diluting out of these inoculum nutrients was important when considering unidentified feed influences, since the fermentation became more dependent on the nutrients supplied by the flask additions in each succeeding 24-hour period. For this reason, consideration was given only to fermentations from the sixth through the 10th day.

The live dried yeast used was secured from a commercial source. The feeds tested were added at two levels corresponding to 9.9 and 21.7 percent respectively of the total air-dry material placed daily in each flask unless given otherwise.

The manure extract was prepared as described by Burroughs *et al.* (1950a).

The aqueous and ethanol extracts of soybean oil meal were prepared by the method of Thornberry and Shanahan (1951).

The composition of the semi-purified rations individually fed to two groups of four lambs each is presented in table 1. The basal ration is believed nutritionally complete for lambs with respect to known nutrient requirements. Most of the nitrogen in the ration was supplied by urea rather than protein sources since the unidentified factor has been shown in artificial rumen studies to be present in a variety of protein feeds. Casein was placed in the basal ration in such an amount that the nitrogen supplied from the casein would equal the nitrogen supplied by the yeast in the second ration. Five percent yeast was used as a source of the unidentified factor since the artificial rumen studies indicated yeast to be one of the more potent sources.

The lambs were full-fed for a period of 8 weeks in individual pens

bedded with shavings during which time feed consumption and live-weight gains were observed.

Results and Discussion

Various feedstuffs when added singly to rumen fermentation flasks stimulated cellulose digestion whereas other feeds failed to exert a stimulating influence (table 2). Soybean oil meal, linseed oil meal, wheat bran, distillers dark grains, corn and yeast stimulated cellulose

TABLE 1. COMPOSITION OF SEMI-PURIFIED RATIONS FED TO LAMBS

Ration Ingredient	Basal Ration	Yeast Ration
	lb.	lb.
Wood cellulose (Solka-floc)	30.00	30.00
Corn starch	33.00	31.00
Corn sugar	24.14	24.10
Lard	3.00	3.00
Urea (crystalline)	3.10	3.10
Crude casein	2.96	....
Yeast (Torula)	...	5.00
Mineral mixture [1]	3.50	3.50
Methionine	0.20	0.20
Choline chloride	0.10	0.10
Vitamins A, D and E [2]	+	+

[1] The mineral mixture was made up as follows: mono-calcium phosphate 9600 gm., cobalt sulfate 2 gm., copper sulfate 15 gm., magnesium sulfate 12 gm., manganese sulfate 113 gm., potassium iodide 1 gm., ferric citrate 421 gm., zinc chloride 11 gm., sodium chloride 2000 gm., potassium carbonate 8000 gm., and calcium fluoride 8 gm.

[2] Per 100 lb. of ration 125,000 units of synthetic vitamin A was added, 15,000 units of vitamin D as Delsterol, and 750 mg. of vitamin E as Alpha Tocopherol.

digestion to the greatest degree, while animal by-products for the most part, vitamins and casein hydrolysate plus purine bases had no apparent stimulation on cellulose digestion.

Replicates were carried out in most instances and a difference in digestion of 12 percentage points was estimated to be significant at the 5 percent probability level.

It was uncertain whether the factor responsible for the stimulation derived from one particular feedstuff was similar to the factor present in another feedstuff capable of bringing about a similar stimulation. Results obtained with combinations of feedstuffs, shown in table 3, indicate no additive effect upon cellulose digestion when combinations of feedstuffs were tested. It would appear that the stimulatory factor present in one feed must therefore be similar to that present in another

feed. In this connection a point of interest is whether roughages contain a factor stimulatory to cellulose digestion similar to that found in certain grains and protein-rich feeds. Three roughages were accordingly tested for the presence of the factor by adding them in varying proportions with Solka-floc. The results are given in table 4.

TABLE 2. STIMULATING INFLUENCE OF INDIVIDUAL FEEDS UPON CELLULOSE DIGESTION BY RUMEN MICROORGANISMS

(Stimulation Expressed as Subtraction of Digestion Obtained in Negative Control Flask from Digestion Obtained in Flask Containing Feed Addition)

Feed Additions to Basal Flask Constituents of Wood Cellulose, Urea and Minerals	Level of Addition	
	Lower	Higher
Soybean oil meal (44% protein)	21	25
Linseed oil meal (34% protein)	21	27
Cottonseed oil meal (42% protein)	8	6
Wheat bran	39	..
Distillers dark grains	14	13
Distillers dried solubles	14	13
Ground yellow corn	15	33
Grey shorts	7	8
Fish meal (60% Menhaden)	5	16
Meat and bone scraps (50% protein)	3	0
Liver and glandular meal	0	0
Dried skim milk	7	..
Live dried baker's yeast	17	3
Bacto yeast extract	27	34
Vitamin B_{12} (5 mcg. per flask)	0	..
Casein hydrolysate (20 ml. per flask)[1]	0	0
Vitamin mixture (1 ml. per flask)[2]	0	..

[1] One mg. of each of the following were added to the casein hydrolysate: cysteine, tryptophane, adenine, guanine and uracil.

[2] Composition of 1 liter of vitamin mixture: biotin 11.1 mg., calcium pantothenate 111 mg., choline chloride 3.1 mg., ascorbic acid 2.78 gm., folic acid 30.6 mg., inositol 11.1 gm., niacin 0.61 gm., para-amino benzoic acid 30.6 mg., thiamine 83.3 mg., riboflavin 50 mg., pyridoxine 83.3 mg., 2-methyl-napthoquinone 30.6 mg., vitamin B_{12} 0.36 mg., and vitamin A acetate 1,600,000 international units.

The early blue grass hay (harvested May 24, 1951) proved very beneficial in stimulating cellulose digestion. Corncobs, although less potent than the blue grass hay, nevertheless stimulated cellulose digestion substantially at the higher ratios. Alfalfa meal stimulated cellulose digestion at each of the various ratios. This evidence suggests that certain roughages like grain and certain other concentrate feeds contain an unidentified factor helpful to cellulose digestion in rumen fermentation.

Cow manure extract (CME), which has been shown by Burroughs

TABLE 3. STIMULATING INFLUENCE OF COMBINATION OF FEEDSTUFFS UPON CELLULOSE DIGESTION BY RUMEN MICROORGANISMS

(Stimulation Expressed as Subtraction of Digestion Obtained in Negative Control Flask from Digestion Obtained in Flask Containing Feed Additions)

Feed Additions to Basal Flask Constituents of Wood Cellulose, Urea and Minerals	Stimulation
Alfalfa meal (5%)	6
Soybean oil meal (10%)	34
Linseed oil meal (10%)	15
Distillers dark grains (5%)	19
Grey shorts (10%)	18
Cottonseed meal (10%)	15
Live dried yeast (2%)	29
Alfalfa (5%)—soybean meal (10%)	34
Alfalfa (5%)—linseed meal (10%)	8
Alfalfa (5%)—distillers grains (10%)	10
Alfalfa (5%)—grey shorts (10%)	10
Alfalfa (5%)—cottonseed meal (10%)	16
Yeast (2%)—soybean meal (10%)	36
Yeast (2%)—distillers grains (5%)	18

et al. (1950a) to be a potent source of the unidentified factor, was used primarily in the fractionation studies (table 5). The sample of cow manure extract used in these studies was also potent in its ability to stimulate and maintain cellulose digestion over extended

TABLE 4. THE INFLUENCE OF VARYING PROPORTIONS OF ROUGHAGES AND SOLKA-FLOC UPON CELLULOSE DIGESTION BY RUMEN MICROORGANISMS

Proportion Solka-floc to Roughage Added to Flask	Cellulose Digested (%) 6th Through 10th Days
100% Solka-floc and 0% alfalfa meal	44
75% Solka-floc and 25% alfalfa meal	59
50% Solka-floc and 50% alfalfa meal	75
25% Solka-floc and 75% alfalfa meal	72
100% Solka-floc and 0% corncobs	44
75% Solka-floc and 25% corncobs	39
50% Solka-floc and 50% corncobs	69
25% Solka-floc and 75% corncobs	66
100% Solka-floc and 0% blue grass hay	44
75% Solka-floc and 25% blue grass hay	74
50% Solka-floc and 50% blue grass hay	86
25% Solka-floc and 75% blue grass hay	80

periods. When cow manure extract and a 5 percent yeast extract solution were respectively passed over ion-exchange resins, their respective potencies were only slightly reduced and the eluates from the resins of CME did not stimulate cellulose digestion, indicating that

TABLE 5. STIMULATING INFLUENCES OF FEED FRACTION AND MANURE EXTRACT UPON CELLULOSE DIGESTION BY RUMEN MICROORGANISMS

(Stimulation Expressed as Subtraction of Digestion Obtained in Negative Control Flask from Digestion Obtained in Flask Containing Test Fraction)

Addition to Basal Flask Constituents of Wood Cellulose, Urea and Minerals	Stimulation [1]
Stock cow manure extract (CME 20 ml.)	51
CME passed through Nalcite HCR and Amberlite 410 resins (20 ml.)	45
Eluate from above resins (20 ml.)	3
CME after removal of protein by HCl precipitation (20 ml.)	49
Protein precipitate from HCl treatment (20 ml.)	0
CME after removal of protein with $ZnSO_4$ (20 ml.)	28
Protein precipitate from $ZnSO_4$ treatment (20 ml.)	8
CME passed over Norite (20 ml.)	27
Norite eluate with acetone (20 ml.)	27
Norite eluate with ethanol (20 ml.)	35
Norite eluate with ether (20 ml.)	0
Aqueous extract soybean meal (18% of flask dry matter)	25
70% ethanol extract soybean meal (18%)	10
95% ethanol extract soybean meal (18%)	9
Ash from aqueous extract soybean meal (18%)	4
Bacto yeast extract passed through Nalcite HCR and Amberlite 410 resins (9% of flask dry matter)	42
Ash from bacto yeast extract (9%)	0
Live dried baker's yeast (5% of flask dry matter)	24
Autoclaved dry baker's yeast (5% of flask dry matter)	21
Ash of baker's yeast (5%)	7
Aqueous extract baker's yeast (5%)	17

[1] Stimulations greater than 12% are estimated to be significant at the 5% probability level.

the unidentified factor was not absorbed as a mineral. Precipitation of the protein in CME with hydrochloric acid did not remove the unidentified factor nor did the precipitate obtained show any activity (table 5). Cow manure extract which was treated with hydrochloric acid and then with alkaline-zinc sulfate to remove the protein lost some of its stimulating influence on cellulose digestion and the precipitate obtained gave but a slight and insignificant increase in cellulose digestion.

Treatment of CME with Norite indicated that the factor could be adsorbed on Norite, and successive elutions with acetone, ethanol, and ether showed the factor to be soluble in acetone, ethanol and questionably so in ether. Aqueous and ethanol extracts of soybean oil meal indicated that the factor was water soluble and soluble in low concentrations of ethanol. The ash of the water extract of soybean oil meal, yeast extract, and live dried yeast did not significantly influence cellulose digestion. Antoclaving of a 5 percent suspension of live dried baker's yeast and the removal of the yeast cells by filtering

TABLE 6. INFLUENCE OF FEEDING YEAST UPON LAMB LIVEWEIGHT GAINS

Ration Designation	Lamb No.	Av. Daily Ration 56-Days	Initial Weight	Final Weight	Av. Daily Gain 56-Days
		lb.,	lb.	lb.	lb.
Basal	13	1.3	62	58	—.07
	23	1.7	65	67	0.04
	33	1.6	60	67	0.12
	43	1.8	58	65	0.12
	Av.	1.6	..	..	0.05
Yeast	12	2.1	62	74	0.21
	22	2.4	63	80	0.30
	32	1.6	61	64	0.05
	42	2.8	59	75	0.29
	Av.	2.2	..	..	0.21

through a bacteriological filter did not appreciably effect the ability of the factor to stimulate cellulose digestion by rumen microorganisms.

The identity of the factor which favorably influences cellulose digestion is not known. Its significance to the nutrition of cattle and sheep also cannot be fully appraised. The results obtained in the lamb feeding experiment (table 6), however, suggest that the factor is beneficial in maintaining appetite or feed consumption in lambs as well as improving rate of gain. The lambs receiving the ration containing yeast as a source of unidentified factor consumed 2.24 lb. of feed daily per lamb and made daily liveweight gains of 0.21 lb., compared with 1.58 lb. of feed consumed and 0.05 lb. daily gain made by lambs not receiving yeast. It appears that yeast supplies an unidentified factor of importance to growth of lambs which parallel the observations made with yeast in supplying an unidentified factor helpful to cellulose digestion by rumen microorganisms.

From the standpoint of feeding practice, further experimental work is required in determining the extent to which this factor is available in adequate quantities. The evidence presented in this paper suggests that the material is quite generally distributed in the major feeds consumed by cattle and sheep; however, this widespread distribution does not preclude the possibility of inadequacy in present-day ruminant rations. Beeson and Perry (1951, 1953) have shown improved liveweight gains in cattle receiving yeast supplements added to a ration high in corncobs and soybean oil meal. Klein and Muller (1941) and Thompson and Tosic (1949) showed a stimulation from yeast upon rate of gain in sheep consuming a semi-purified and a natural ration respectively.

Summary

Several of the more common feeds fed to cattle and sheep were tested using the artificial rumen technique in determining the presence or absence of an unidentified factor stimulatory to rumen microorganisms in the digestion of cellulose. A limited number of feeds and cow manure extract were fractionated in different ways in characterizing the chemical and physical properties of the factor. A lamb feeding experiment was carried out using a semi-purified ration in determining the significance of the factor in stimulating appetite and weight gains in feeder lambs. The results indicated that the factor is fairly widespread in common feeds fed to cattle and sheep, both concentrate feeds and roughages. Yeast and manure extract were particularly rich sources of the material. Fractionation of these materials indicated the factor to be heat stable, and soluble in water and low concentration of ethanol. It was absorbed on Norite and eluted with acetone and ethanol. Absorption did not occur on ion-exchange columns and ashing destroyed the factor, indicating that the active material was not a mineral but rather an organic substance. Since removal of proteins by precipitation failed to remove the active principle, and various B-vitamin and amino acid supplements failed to stimulate cellulose digestion, the factor does not appear to be a B-complex vitamin or a protein. The factor stimulated appetite and liveweight gains in lambs receiving a semi-purified ration paralleling the favorable activity noted with rumen microorganisms.

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ALTERATION OF DAILY GAIN, FEED EFFICIENCY AND CARCASS CHARACTERISTICS IN BEEF CATTLE WITH MALE HORMONES [1, 2]

MARTIN J. BURRIS, RALPH BOGART and A. W. OLIVER

BULL calves have been found to gain more rapidly and require less feed per unit gain than heifer calves of similar age and breeding according to work by Dahmen and Bogart (1952). These differences between sexes may be due to differences in the level of male hormones in the two sexes. Testosterone has been shown to have a growth stimulating effect in the human by Kenyon (1938) and by McCullagh and Rossmiller (1941). Work by Papanicalaou and Falk (1938) with immature guinea pigs indicated a definite hypertrophy of the temporal muscle and other muscles due to the administration of testosterone propionate. This induced muscular enlargement was offered as an explanation for the higher muscular development of the male animal.

In farm animals much work has been done in an attempt to increase gains, feed efficiency, and carcass quality with male hormones. Sleeth *et al.* (1952) reported that weanling pigs given 1 mg./kg. of body weight of testosterone propionate weekly gained .15 lbs. more per day, but were not different from controls in feed consumption, thickness of back fat, tenderness, palatability, and carcass grades. Woehling *et al.* (1951) found no significant effects on rate of gain, feed efficiency, or several carcass characteristics in pigs due to the implantation of two 15 mg. pellets of testosterone at 12 week intervals. The work of Andrews *et al.* (1949) indicated that the subcutaneous implantation of 10 mg. of testosterone significantly increased the gains and feed efficiency of wether lambs during a 68 day feeding period and, also, that the carcass quality and market value appeared to be improved by this treatment. O'Mary *et al.* (1952) reported that weekly injections of 20 mg. of testosterone increased daily feed intake in ewe lambs and decreased the number of days required to reach a weight of 100 pounds in both ewe and wether lambs; but lambs receiving a

[1] This study was conducted in cooperation with Bureau of Animal Industry, U. S. Department of Agriculture, and State Experiment Stations under Western Regional Project W-1 on Beef Cattle Breeding Research.

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12 mg. implant of testosterone showed no significant difference from control lambs in rate of gain and feed efficiency.

Dinusson *et al.* (1950) observed a temporary growth stimulus and increased daily feed consumption in beef heifers given an intramuscular injection of 50 mg. of testosterone propionate followed by a second injection of 32.5 mg. 56 days later. A second group of beef heifers receiving a subcutaneous implant of a 50 mg. pellet of testosterone propionate also showed a short growth stimulus but the overall growth rate, carcass quality and dressing percentage were not altered by the hormone treatment. Andrews *et al.* (1950) reported that yearling steers receiving a 180 mg. implant of testosterone at beginning of the feeding trial were not significantly different from control steers in feed efficiency, rate of gain, or carcass quality.

Experimental

A group of twelve heifer and twelve steer calves were used in this experiment which was during the winter and spring of 1950–51. Three heifer and three steer calves were placed in the testosterone group and received weekly intramuscuar injections of 1 mg. of testosterone per kg. of body weight after reaching 500 pounds live weight. Three heifer and three steer calves were placed in the methyl androstenediol group and received weekly intramuscular injections of 1 mg. of methyl androstenediol per kg. of body weight. Six heifer and six steer calves served as controls and received no hormonal treatment.

Heifers and steers were kept in separate pens during and prior to the test period. Six animals were confined to each pen. The mangers were so constructed that each calf could be tied to its manger and have access only to feed weighed out to it. Calves remained tied for approximately four hours after each of the two daily feedings. Water was supplied at all times in automatic drinking cups installed along the mangers. Wood shavings were used for bedding to assure that nothing would be eaten other than the ration.

The roughage fed was high-quality alfalfa hay. The concentrate mixture consisted largely of rolled barley, ground oats and dried beet pulp with several sources of protein included.

At weights from 500 to 600 pounds the ratio was 1 concentrate to 3 hay; from 600 to 700 pounds, 1 concentrate to 2 hay, and from 700 to 800 pounds 1 concentrate to 1 hay. The overall ratio of concentrate was somewhat narrower than 1 to 2 because of the small amounts of hay which were refused.

Each calf was placed on test when it reached 500 pounds and taken off the test when it reached 800 pounds. When each animal reached 800 pounds it was slaughtered at a nearby slaughterhouse and information on size and condition of various glands and organs secured. Dressing percent was based on the chilled carcass weight and the 24-hour-shrink. Carcass measurements were taken on the left side. The left side was weighed separately and cut into the wholesale cuts.

TABLE 1. THE EFFECT OF MALE HORMONES AND SEX OF CALF ON AVERAGE DAILY GAIN

	Treatment Groups		
Sex Groups	Testosterone	Methyl Androstenediol	Control
Steers	2.68*	2.22	2.39
Heifers	2.54*	1.94	2.01
Average	2.61*	2.03	2.20

* Significantly different from controls.

The percentage of the cuts was computed using the weights of the cuts and the weight of the side, both taken on the left side of the chilled carcass. The standard method of cutting the wholesale or primal cuts was followed except the loins were "Bootjacked" (all the knuckle piece was left in the loin). A five rib chuck was cut; the rib section contained seven ribs.

Rate of gain and feed consumption per 100 pounds gain were calculated from feed consumption and weight records. The analysis of variance (Snedecor, 1948) was used to determine the significance of the various experimental effects using the five percent level.

Results

Testosterone produced marked increases in the average daily gain of both heifer and steer calves (table 1). Heifer calves treated with testosterone gained 0.53 pound more per day during the 500 to 800 pound test period than control heifer calves. Testosterone-treated steer calves gained 0.29 pound more per day than control steer calves. Although the response of heifers to testosterone was greater than that of steer calves the interaction of treatment and sex was not significant. Heifers receiving testosterone gained 0.15 pound more per day than control steers and only 0.14 pound less per day than testosterone-treated steers. The control heifers, however, gained 0.38 pound less than control steers.

Calves receiving testosterone required much less feed per unit gain than control calves (table 2). Heifer calves receiving testosterone required only 3.93 pounds TDN (total digestible nutrients) per pound gain while control heifers required 5.01 pounds of TDN per pound gain. Testosterone-treated steer calves required only 3.65 pounds of TDN per pound gain while control steers required 4.30 pounds of TDN per pound gain. The difference in TDN requirements per unit gain between the testosterone-treated heifers and steers (0.24 pounds) was much less than that between the control heifers and steers (0.77 pounds). This also indicates that testosterone may have a greater effect in the heifers than in the steer calves.

TABLE 2. THE EFFECT OF MALE HORMONES AND SEX OF CALF ON POUNDS TDN REQUIRED PER 100 POUNDS GAIN IN BODY WEIGHT

Sex Groups	Treatment Groups		
	Testosterone	Methyl Androstenediol	Control
Steers	365*	453	430
Heifers	393*	501	507
Average	379*	477	468

* Significantly different from the controls.

There were no significant effects of methyl androstenediol on average daily gain or feed required per unit gain of the calves in this trial.

Of the two male hormones used only testosterone produced any marked effects on the weights of wholesale cuts (table 3). Testosterone-injected cattle in this experiment had 2.8 percent more weight in the rounds than cattle in the control group. Heifers treated with testosterone had 2.3 percent more chuck than control heifers. The testosterone-injected cattle, both heifers and steers, had a significantly less percentage of untrimmed loins. The control lot had 2.77 percent more loin than the testosterone-treated cattle. Methyl androstenediol had no effect on the percentage of the cuts.

Neither testosterone nor methyl androstenediol had significant effects on the length from "H" bone to first rib, "H" bone to hock, or length of the rib eye section at the twelfth rib (table 4). However, the calves receiving either male hormone had a significantly wider rib eye section at the twelfth rib than the control calves.

TABLE 3. THE EFFECT OF MALE HORMONES ON PERCENTAGE OF WHOLESALE CUTS OF BEEF HEIFERS AND STEERS

Treatment	Ave. Live Wt.	Dressing Yield	Round	Flank	Loin	Chuck	Rib	Plate	Brisket	Shank	Hind Quarter
	lbs.					percentage					
Heifers											
Testosterone	765.0	59.7	22.9*	6.27	20.77*	27.8*	8.75	6.85	3.13	3.53	50.0
Methyl androstenediol	776.6	58.3	20.9	5.93	23.57	25.1	8.46	8.16	4.43	3.26	50.4
Controls	765.8	61.1	20.1	6.18	24.58	25.5	8.34	7.86	3.78	3.06	50.9
Steers											
Testosterone	766.0	58.2	24.7*	4.82	19.61*	27.0	8.35	6.43	4.34	3.87	49.2
Methyl androstenediol	775.0	58.6	21.4	6.03	21.21	26.9	8.71	8.16	4.23	3.61	48.8
Controls	761.7	58.8	22.1	6.01	21.28	27.5	8.26	7.50	3.98	3.56	49.4
All calves											
Testosterone	765.5	58.9	23.8*	5.55	20.20*	27.4	8.55	6.64	3.73	3.70	49.5
Methyl androstenediol	775.8	58.4	21.2	6.03	22.39	26.0	8.58	8.16	4.33	3.43	49.6
Controls	763.8	60.0	21.1	6.10	22.97	26.4	8.30	7.69	3.88	3.30	50.1

* Significantly different from the controls.

TABLE 4. THE EFFECT OF MALE HORMONES ON THE MEASUREMENTS AND GRADES OF THE CARCASSES OF BEEF CALVES

Treatment	Rib Eye		"H" Bone to 1st Rib	"H" Bone to Hock	Carcass Grade
	Width	Length			
	(inches)		(inches)	(inches)	
Testosterone	2.56*	5.48	43.71	26.58	5 choice 1 good
Methyl androstenediol	2.45*	5.48	43.83	27.75	6 choice
Controls	2.12	5.38	43.92	27.77	12 choice

* Significantly different from the controls.

Summary and Conclusion

The weekly intramuscular injection of testosterone at the rate of 1 mg./kg. of body weight resulted in an increase in rate of gain and a decrease in feed required per unit gain. Testosterone-treated heifers had a higher percent of chuck than control heifers and testosterone-treated heifers and steers had a higher percent of round and a lower percent of loin than control calves.

The weekly intramuscular injection of methyl androstenediol at the rate of 1 mg./kg. of body weight had little or no effect on rate of gain, economy of gain or carcass characteristics.

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THE RELATIONSHIP OF SURFACE AREA TO HEAT TOLERANCE IN JERSEYS AND SINDHI-JERSEY (F_1) CROSSBRED COWS[1]

R. E. McDowell, Douglas H. K. Lee[2] and M. H. Fohrman

U. S. Department of Agriculture

FROM the turn of the century, investigators have been fully aware of the importance of surface area in the exchange of heat between an animal and its surroundings. It has become standard practice for metabolic rates, for example, to be expressed in terms of kilocalories per square meter of body surface per hour. It would seem reasonable, therefore, to assume that the greater the surface area of an animal in proportion to weight, the more readily will heat loss occur; so that an animal with greater proportional surface area might be expected to have a greater heat tolerance.

This line of presumptive reasoning has promoted the belief that the greater heat tolerance of zebu as compared with European-type cattle may be attributed to the extensive dewlap, navel fold, and penile sheath which are characteristic of the former. Kibler and Brody (1950) have stated, indeed, that the proportional surface area of Brahman[3] cattle examined by them was 12 percent greater than that of Jerseys of the same weight, and that their heat tolerance was higher.

One of the present authors (D. H. K. Lee) made similar observations several years ago on two breeds of hen—White Leghorns, which have extensive wattles and comb, and Australorps, in which these appendages are small. He found, however, that when the appendages were removed from the former, their superior heat tolerance was in no way disturbed. On reflection, it becomes apparent that a proportionately greater surface area can be regarded as giving proportionately greater opportunities for heat loss only so long as the extended surface maintains comparable physical relationships with the atmosphere. In the case of the hens, it transpired that while the appendages held a relatively large quantity of blood, the rate of blood flow through them, and thus the facilities for convective heat transfer, was relatively low. In the case of cattle it would need to be established that the

[1] These studies were conducted by the Bureau of Dairy Industry at the Agricultural Research Center, Beltsville, Maryland.

[2] Professor of Physiological Climatology, Johns Hopkins University, Baltimore, Md.

[3] Mason (1951) defines Brahman as "originated from Ongole, Kankrej, Gir, and Kishma Valley breeds imported 1850–1906, probably with some European blood."

appendages had a blood flow comparable to that of the general skin, before their advantage as heat exchangers could be assumed.

The simple reasoning is further complicated by the fact that the appendages would increase the gain of heat by the animal through conduction from the air whenever the air temperature rose above that of the body, so that the superiority would be turned into an inferiority at air temperatures much above 102° F., unless the skin were able to maintain an important degree of cooling by evaporation (a point which is warmly disputed and on which interesting studies are being made).

In the course of cross-breeding work being conducted as part of the Southern Dairy Cattle Breeding Project, two groups of dairy cattle have been established at Beltsville, one of purebred Jerseys, another of F_1 crosses of Red Sindhi (a Zebu breed) on Jerseys. These two groups show distinct differences in heat tolerance, and in the process of endeavoring to establish the animal characteristics responsible for these observed differences, the question of proportional surface area naturally called for study.

Methods

Measurement of Surface Area

Brody and Elting (1926) devised an instrument for measuring the surface area of cattle, in which the revolutions of a wheel of known width and circumference were counted while it was run in systematic fashion over the animals surface. Further results obtained by this method were published at later dates (Brody, Comfort and Matthews, 1928; Brody, 1945).

The instrument used in the studies now being reported employs the same principle. It consists of two wheels (figure 1), the circumference of which is known, mounted a fixed distance apart, and geared to a revolution counter. One wheel has a roughened surface, which rubs off chalk from a stick fixed in a holder, and deposits it on the surface over which it is running. The mechanism is mounted on a handle, by which it can be pushed along. The area covered is given by the product:

$A = (\text{circumference of wheel}) \times (\text{distance between centers}) \times (\text{number of revolutions})$.

The surface area is measured on one side of the animal with the animal standing squarely on all four feet, in the following steps.

1. Starting from the shoulder, with the counter set at zero, the integrator is pushed along the back, with the plain wheel running along the center line of the spinal column.
2. When the base of the tail is reached, the integrator is lifted off, and a second run started from the shoulder, with the plain wheel now running along the chalk line made by the marking wheel during the first run.

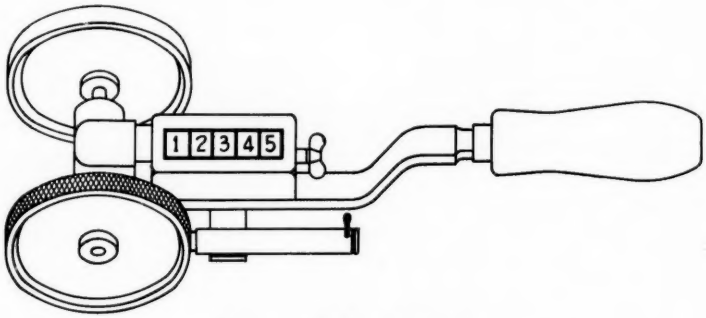

Figure 1. Surface integrator.

3. This process is repeated until there remains only one strip before the middle line of the belly and chest is reached. The counter is now read.
4. The counter is reset at zero and a run made over the last strip; but since this strip will seldom have the same width as the distance between the wheels, the count must be reduced by multiplying it by the ratio between the width of the strip and the distance between the wheels (actually the distance between the outer edge of one wheel and inner edge of the other).
5. The counter is reset at zero and run over the area between the shoulder and the head in vertical strips from the lower midline to the center of the spinal column. At the time of measurement the animal's head is turned in the opposite direction to remove the gross wrinkles in the skin, and the hand is held on the opposite side of the dewlap.
6. The fore leg and the rear leg are measured with the integrator by placing the feet wide apart while the integrator is run in horizontal strips around the legs down to the vicinity of the knee joint.

7. The remaining parts are not measured with the surface integrator. Their surface is obtained by approximate calculation. The lower legs are treated as cylinders. A measuring tape is used to take the length from the lower mark of the integrator to the top of the hoof, and several circumferences from which an average is taken. The surface area is given by multiplying the average circumference by the length.
8. The tail is measured from the base to the bony tip, and an average circumference obtained from several measurements. The surface area again equals the product of the length and the average circumference.
9. The length of the head is measured from the top of the poll to the mouth, and the width between the bases of the ears. The surface area is given by half the product of the length and width.
10. The area of the ear is determined by measuring the outside length from base to tip, and the width of the flattened ear at the middle of its length, and multiplying them together.
11. The total surface area of the animal is given by the sum:
    $S=2(m+f+r+e)+t+h$
    Where S is the total surface area
    m is the total of all areas measured by the integrator
    f is the area of the fore leg
    r is the area of the rear leg
    e is the area of the ear
    t is the area of the tail
    h is the area of the head

Measurements made in this way on both sides of the animal showed agreement to within .043 percent, so that the restriction of measurement to only one side, apart from the head and tail, seems justified.

Heat Tolerance Test

All of the female animals obtained in the experimental cross-breeding program at Beltsville are subjected to a standard test hot atmosphere at intervals through their life, in order to determine their reactions and tolerance. The test atmosphere is at 105° F. with a vapor pressure of 34 mm. Hg (wet bulb temperature of 92° F.), and the animals are exposed to it for six hours. Rectal temperature, respiration rate, pulse rate, visible wetness of skin, and other observations on behavior are made hourly during this period.

Periodic testing is commenced at six months of age, and carried out at approximately two-month intervals thereafter, with the exception of the first lactation period, which is left undisturbed for record purposes. Testing is not carried out, however, during the 45 days before expected parturition.

The test animals are placed in the heat chamber on the afternoon prior to the test, but without any heating. Water, grain, and hay are allowed *ad libitum* during the afternoon. Grain is also offered in the morning. Feed is withdrawn before the test, and no feed or water is offered during the six-hour period of the test.

The tolerance pattern of each adult animal is known from these routine tests, and can be compared with other characteristics measured on the animals. Consequently it was decided to take the test tolerances for the two groups of animals from these records rather than to conduct special tests. Tolerances obtained when the animals are dry, or as 18 to 22 month old heifers, are the most comparable; but comparability during lactation can still be expected if care is taken to compare only animals showing fairly similar levels of milk production. To meet possible objections, the tolerances of animals used in this study will be given in two ways: (I) when dry; (II) at the routine test closest to the time of measurement. In addition, the average tolerance of animals of the same breed combination, and producing at the same level as these animals were at the time of measurement, will be given for comparison.

Results and Discussion

From table 1 and figure 2 it will be seen that the two groups of animals are strikingly similar in the measurements made. The Jerseys are a little larger, though not significantly so; but the ratio of surface area to body weight is identical in the two groups. The correlation and regression coefficients of surface area on body weight are also substantially the same for the two groups. When the surface area is compared, not to body weight, but to the two-thirds power of body weight (figure 3), the position is not materially changed.

When the heat tolerance of the two groups is examined, however, a difference is found. In table 2 the heat tolerance of the two groups is examined on three bases. In the upper part of this table the groups are compared in terms of the reaction of the same cows to the standard hot atmosphere when the cows were dry. This has the advantage of

comparing them under similar metabolic conditions; and it will be seen that the Jerseys show twice the response of the crossbreds.

In the middle part of the table the groups are compared in terms of the reaction of the same cows at the routine tolerance test carried out closest to the date of measurement. This has the advantage of

TABLE 1. COMPARISON OF WEIGHT TO SURFACE AREA, AND (WEIGHT)$^{.67}$ TO SURFACE AREA, FOR 20 JERSEYS AND 20 SINDHI×JERSEY CROSSES

Item	Jerseys		Crosses	
	Mean	Standard Error	Mean	Standard Error
Surface area (sq. m.)	4.30	0.054	4.12	.068
Body weight (kg.)	461.8	9.39	441.9	9.83
S.A. (sq. cm.)/B.W. (kg.)	93.58	1.225	93.59	1.461
Correlation between B.W. and S.A.	.716	0.199	.732	0.213
Regression of S.A. on B.W.	.0047	0.0011	.0051	0.0011
(Body weight)$^{.67}$	59.65	.827	57.86	.865
S.A. (sq. cm.)/B.W. (kg.)$^{.67}$	722.2	6.11	712.1	8.15
Correlation between (B.W.)$^{.67}$ and S.A.	.719	0.198	.750	0.206
Regression of S.A. on (B.W.)$^{.67}$	.055	0.0123	.059	0.0122
Age	4 yr. 10 m.	.....	3 yr. 11 m.	.....
Stage of lactation	3.3 m.	.....	2.9 m.	.....
Milk production (lb. FCM)	41.2	1.77	30.2	2.47
Condition *	5.8	.20	7.3	.18

* A quantitative value used to determine the degree of fleshing, using a scale of 1 to 9 (1 for extreme emaciation, 5 for good average covering and 9 for extreme fatness).

comparing the animals close to the time of measurement, but the disadvantage that the state of the animal may have changed (for example, in milk production, health, appetite, etc.) in the interim. It will be seen that the reactions are greater than when the cows were dry, but the Jerseys again show double the response.

In the lower part of the table a comparison is made, not between the reactions of the particular cows measured, but between Jersey and crossbred cows of the general herd having the same level of milk production as the animals at the time that they were measured (see table 1). This has the advantage of compensating for differences in the most influential factor affecting heat tolerance—milk production—but the animals are not always those which were measured. Here again the superior heat tolerance of the crossbred animals is evident.

The position is, therefore, that there are here two groups of animals which show marked differences in heat tolerance whether dry or lactating; but which have practically identical ratios of surface area to body weight. It seems clear, therefore, that it is possible to have important differences in heat tolerance without differences in proportional surface area. In those animals which have very large appendages, such as purebred Brahmans, it is possible that a further advantage is conferred upon them thereby; but the possession of the appendages is, to say the least, not essential to the possession of superior heat tolerance.

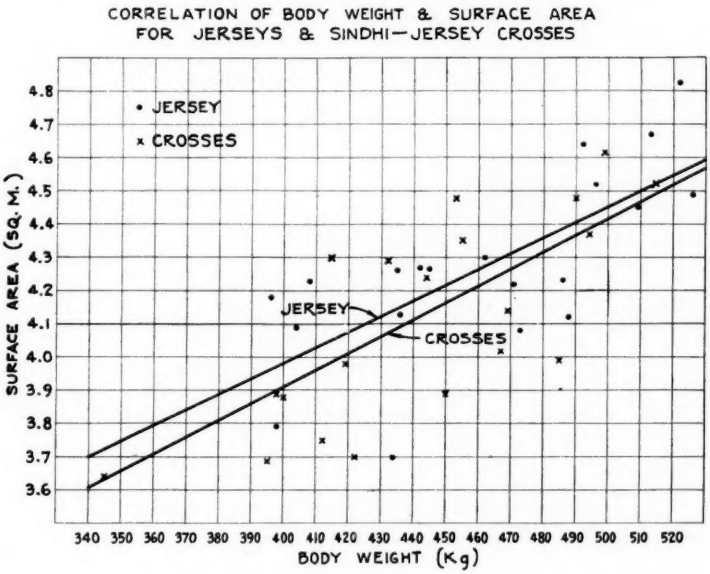

Figure 2.

In view of the fact that the greater dewlap and hump is clearly visible in the crossbred animals, the equality in proportional surface area occasions some surprise. The explanation apparently is that, while the surface area of the crossbred animal is increased by these appendages, that of the purebred Jersey is increased to an almost identical degree by the greater angularity of the hips and rump.

The similarity of the correlation coefficients obtained when surface

area is matched, in the one case against body weight, and in the other against the two-thirds power of body weight, suggests that the relationship between surface area and body weight in the adult animals measured can be just as well represented by a straight line. When figures are taken from the data originally published by Brody and Elting (1926) for Jerseys falling within the same weight range it is

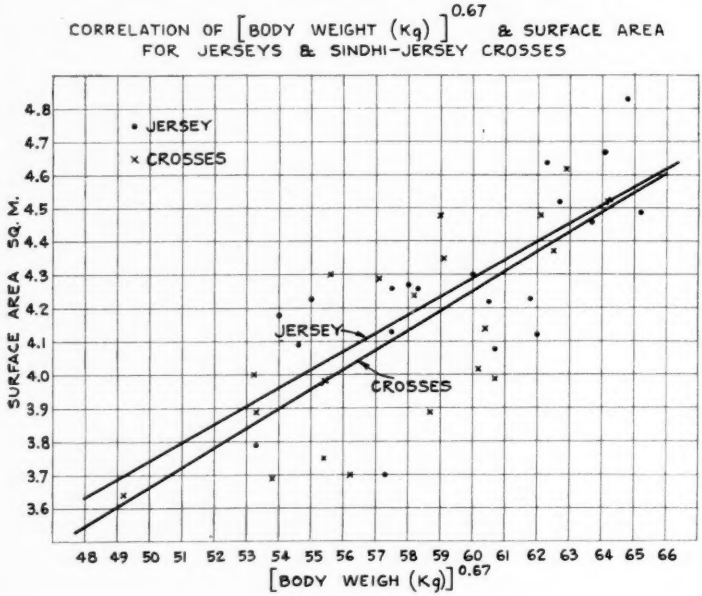

Figure 3.

seen that they too are well fitted by a straight line. Calculation shows that their data have a correlation coefficient of .923 when surface area is matched against body weight, and one of .928 when it is matched against the two-thirds power of body weight. The regression coefficients are very similar to those obtained with the animals reported here, .0048 for surface area on body weight and .0545 for surface area on the two-thirds power of body weight. It would seem that the additional arithmetic involved in using the two-thirds power of body weight for determining proportional surface area is justified only when the range of body size is very extensive, as would be the case when

animals of all ages from the very young to fully mature animals were being studied.

Summary

The surface area was measured on 20 adult Jersey and 20 adult Sindhi-Jersey crossbred cows with a surface integrator, the construction and use of which is described. The areas were compared

TABLE 2. COMPARATIVE REACTIONS OF JERSEYS AND SINDHI× JERSEY CROSSES TO HOT CONDITIONS (6 HOURS EXPOSURE TO 105° F. DRY BULB AND 92° F. WET BULB)

	Jerseys		Crosses	
Time	Rectal Temperature (° F.)	Standard Error	Rectal Temperature (° F.)	Standard Error
	Measured Animals Tested as Dry Cows			
Initial	101.16	.072	101.20	.076
Mean [1]	102.82	.177	102.03	.088
Difference	1.70	.167	.87	.093
Number of animals	20	....	20	....
	Measured Animals at Nearest Test			
Initial	101.18	.089	101.50	.134
Mean [1]	103.36	.253	102.62	.144
Difference	2.18	.264	1.14	.112
Number of animals	20	....	20	....
	Herd Jerseys Producing 40 Pounds FCM/Day and Herd Crosses Producing 30 Pounds FCM/Day at the Time of Test			
Initial	101.60	.107	101.65	.061
Mean [1]	104.45	.193	103.12	.172
Difference	2.85	.209	1.57	.105
Number of animals	22	....	20	....

[1] Trapezoidal mean for a 6 hour period.

with the body weights. Neither the ratio of surface area to body weight, nor the ratio of surface area to the two-thirds power of body weight, showed a significant difference between the two groups.

In spite of the close similarity in proportional surface area, the heat tolerance of the two groups was markedly different. This indicates that differences in heat tolerance of animals such as these are not primarily due to differences in proportional surface area even though the presence of large dewlaps, etc., might suggest that such a difference in surface area would be found.

The relationship between surface area and body weight in the animals reported here, and in animals of adult size reported elsewhere

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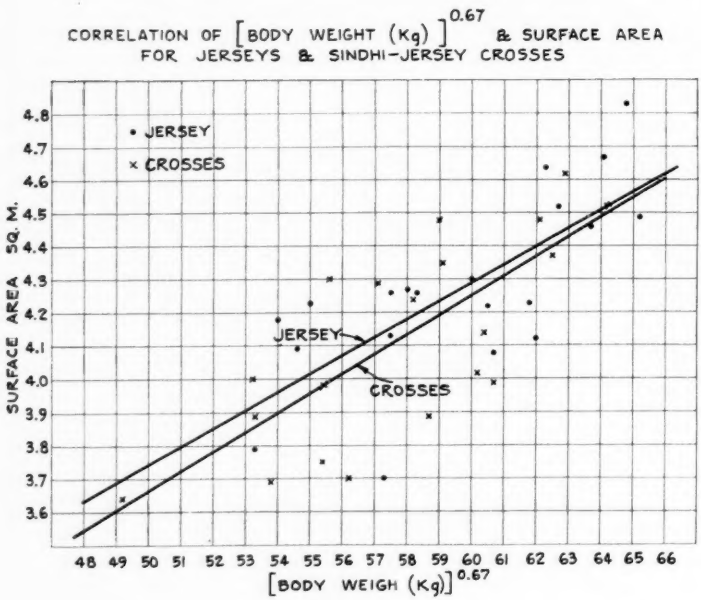

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In spite of the close similarity in proportional surface area, the heat tolerance of the two groups was markedly different. This indicates that differences in heat tolerance of animals such as these are not primarily due to differences in proportional surface area even though the presence of large dewlaps, etc., might suggest that such a difference in surface area would be found.

The relationship between surface area and body weight in the animals reported here, and in animals of adult size reported elsewhere

in the literature, is well enough expressed by a straight line. It is suggested that there is no advantage to be gained from the more complex exponential relationship introduced by using a fractional power of body weight when comparisons are to be made between adult animals.

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REPEATABILITY OF AN EXPERIMENTAL HEAT TOLERANCE TEST AND THE INFLUENCE OF SEASON [1]

R. E. McDowell, C. A. Matthews, Douglas H. K. Lee [2] and M. H. Fohrman

U. S. Department of Agriculture

IT is always highly desirable that a procedure intended for use as a test should give results with a high degree of repeatability. This question arose when it was first decided to measure the heat tolerance of all females in the Beltsville cross-breeding experiment at regular intervals throughout their life, and to compare the tolerances of different breed combinations. It did not prove practicable, however, to establish the repeatability of the results at the outset in the usual way—namely, by repeating the test several times on the same animals. The very fact of frequent repetition on the same animals would certainly tend to set up accumulative effects in them, some of adaptative nature, and some of a reactive nature. Nor was it possible to repeat the test on several animals at longer intervals, since they change in age, pregnancy, milk production, and numerous other features with the passage of months. Reliance had to be placed, therefore, upon careful test design directed to eliminating the major external causes of variation, with the hope that statistical analysis of the results would in time reveal a desirable degree of repeatability.

Such an analysis has recently been made with results which were at first disappointing. But on further analysis it transpired that one factor was responsible for the greater part of the apparent non-repeatability. When statistical correction was made for this one factor, a gratifying degree of reliability was revealed. It is felt that both the experience and the conclusions are of wider importance than usually attached to a more domestic adjustment of procedures.

Nature of Heat Tolerance Test

In the course of cross-breeding work being conducted as part of the Southern Dairy Cattle Breeding Project, two groups of dairy cattle have been established at Beltsville, one of purebred Jerseys, another of F_1 crosses of Red Sindhi (a Zebu breed) on Jerseys. All

[1] These studies were conducted by the Bureau of Dairy Industry at the Agricultural Research Center, Beltsville, Maryland.

[2] Professor of Physiological Climatology, Johns Hopkins University, Baltimore, Maryland.

of the female animals obtained in this program are subjected to a standard test hot atmosphere at intervals through their life, in order to determine their reactions and tolerances. The test atmosphere is at 105° F., with a vapor pressure of 34 mm. Hg (wet bulb temperature of 92° F.), and the animals are exposed to it for six hours. Rectal temperature, respiration rate, pulse rate, visible wetness of skin, and other observations on behavior are made hourly during this period.

Periodic testing is commenced at six months of age, and carried out at approximately two month intervals thereafter, with the exception of the first lactation period, which is left undisturbed for record purposes. Testing is not carried out, however, during the 45 days preceding expected parturition.

The test animals are placed in the heat chamber on the afternoon prior to the test, but without any heating. Water, grain and hay are allowed *ad libitum* during the afternoon. Grain is also offered in the morning. Feed is withdrawn before the test, and no feed or water is offered during the six-hour period of the test.

Measure of Repeatability

The method employed for establishing repeatability is that of determining the intra-animal correlation coefficient in the course of tests repeated at different times on each of a number of animals. The method is essentially that described by Snedecor (1946) and recommended by Lush (1945).

Only the observations of rectal temperature will be discussed in detail here.

Preliminary Analysis of Rectal Temperature Responses

It is well known that the processes of milk production increase the metabolic rate and decrease the heat tolerance of cattle. For this reason, the records were first separated into three groups: heifers (6–22 months of age), lactating cows, and dry cows. Within each group further sortings were made for factors which were thought to be exercising differential influences. The repeatabilities for the unsorted groups, and the effect of these sortings upon the repeatabilities, are given in table 1.

It will be seen that the repeatability obtained on each unsorted group is disappointingly low, and not significantly different from zero,

except in the case of dry cows. Even in that group, the repeatability is not sufficiently high to be very encouraging.

In the heifer group, improvement in the repeatability is obtained only by separating off the older animals (18–22 months of age), and then only in that separated group. Further adjustments for age within

TABLE 1. REPEATABILITY[1] OF MEAN BODY TEMPERATURE RESPONSE[2] TO A STANDARD TEST HOT ATMOSPHERE (6 HRS. AT 105° F. AND 34 MM. Hg VAPOR PRESSURE)

Subgroup	Repeatability	
	Jerseys	Sindhi×Jersey
Heifers		
6–22 months with no age adjustment	0.22	0.17
6–22 months adjusted for age	0.29	0.24
6–10 months with no age adjustment	0.29	0.43
6–10 months adjusted for age	0.27	0.44
12–16 months with no age adjustment	0.10	—0.10
12–16 months adjusted for age	0.08	—0.07
18–22 months with no age adjustment	0.36**	0.29
18–22 months adjusted for age	0.35**	0.27
Dry Cows		
No adjustment for time dry	0.42**	0.46*
Adjusted for length of time dry	0.48**	0.42*
Lactating Cows		
No adjustment for stage of lactation	—0.07	0.19
Adjusted for stage of lactation	—0.03	0.21
Levels of Production (10–40 lb. FCM)		
No adjustment for level of production	0.06	0.20
Adjusted for level of production	0.09	0.12

* Significant at the 5% level.
** Significant at the 1% level.
[1] Coefficient of intra-animal correlation.
[2] Trapezoidal mean for a period of six hours' exposure.

that group bring about no further improvement. (The figures obtained for the cross-bred animals of 6–10 months of age are high, but because of small numbers are not significantly different from zero.)

In the lactating group, adjustment for neither the stage of lactation nor the level of production, results in any improvement in the repeatability.

In the dry group, adjustment for length of time that the animals had been dry brings about no improvement in the figure.

Effect of Season on Rectal Temperature Responses

At Beltsville there is a fairly wide range of annual variation in climatic conditions, which produces correspondingly marked differences in barn temperatures and humidities, as well as in grading conditions. It is reasonable to expect, therefore, that this seasonal variation might have an effect. At first it was thought that the test occasions amongst the animals of any one group would have been randomly distributed

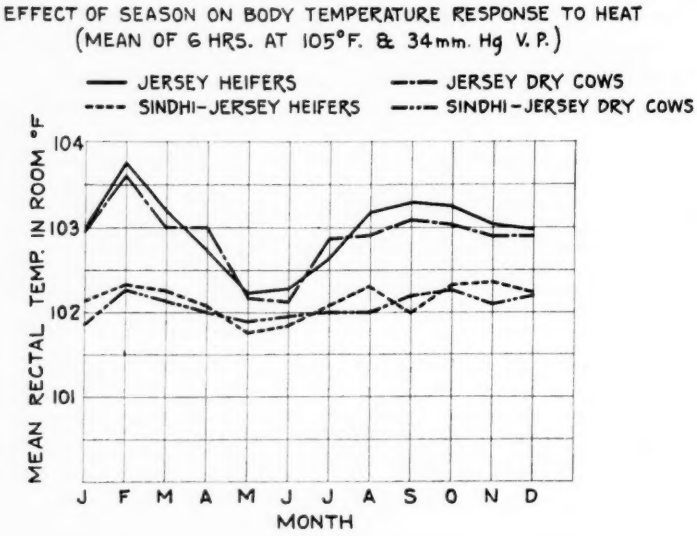
EFFECT OF SEASON ON BODY TEMPERATURE RESPONSE TO HEAT
(MEAN OF 6 HRS. AT 105°F. & 34mm. Hg V. P.)
JERSEY HEIFERS
JERSEY DRY COWS
SINDHI-JERSEY HEIFERS
SINDHI-JERSEY DRY COWS
MEAN RECTAL TEMP. IN ROOM °F
104
103
102
101
J F M A M J J A S O N D
MONTH

Figure 1.

as regards season; but inspection of the records indicated that this was not so. From observations on other animals (unpublished) and from theoretical considerations (Lee and Riek, 1951), it was felt unwise to adopt the arbitrary division of the year into the four customary seasons for the purpose of statistical analysis of seasonal effect. To reveal the seasonal effect, the temperature responses of the heifers and the dry cows to the test atmosphere were plotted by months (figure 1).

The results are interesting. Instead of a simple biphasic curve, with a maximum in summer and a minimum in winter, the curves show two maxima—a greater one in February, and a lesser one in August—and one minimum in May and June. This is particularly observable

with the Jerseys, who have the greater response. The physiological implications of this will be discussed below, but it is clear from these results that the conventional subdivision of the year would not have been at all appropriate. On the basis of these results, the records were sorted into three groups: Those of April–July as a period of low response; those of August–September and February–March combined to constitute a period of high response; and those of October–January as a period of intermediate response.

TABLE 2. REPEATABILITY [1] OF MEAN BODY TEMPERATURE RESPONSE [2] OF HEIFERS (8–22 MONTHS) TO A STANDARD TEST HOT ATMOSPHERE (6 HRS. AT 105° F. AND 34 MM. Hg V.P.)—SORTED BY SEASON

	Apr.–July (low)	Aug.–Sept.; Feb.–Mar. (high)	Oct.–Jan. (intermediate)
Jerseys	0.93**	0.72**	0.60**
Sindhi-Jersey crosses	0.54**	0.67**	0.78**

** Significant at the 1% level.
[1] Coefficient of intra-animal correlation.
[2] Trapezoidal mean for a period of six hours' exposure.

When the heifer group is resorted into these three subgroups, all the coefficients (table 2) rise to highly significant and experimentally satisfying levels. It is clear from these results that season has a marked effect upon the results obtained in short-term responses to test hot atmospheres, and that when comparisons are made between different groups of animals, the records should be inspected for comparability in seasonal incidence, and statistical correction applied for any differences in this respect.

It is not possible to make a similar analysis of the data on dry cows, since the breeding and milking pattern followed brings any one cow to the end of her lactation at approximately the same time of year on each occasion. Repeatability is hardly to be expected in lactating cows without correction for level of production, which affects heat tolerance to a marked degree. The number of records is too small to permit an adequate statistical correction for this highly variable factor, so that again no similar analysis has been attempted for lactating cows.

Probable Mechanism of Seasonal Effect

When an animal is subjected to a stress, the resultant effects upon bodily processes can be conceived as falling into two classes—(1)

those in which the process is displaced by the stress, to which the term of *yield or slip response* can be given; and (2) those which oppose the stress or tend to restore displacements which have already occurred, to which the term of *compensatory response* can be given. When an animal is exposed to heat, the slip phenomena exceed the compensatory, so that a net displacement can be seen. Unless the stress is too great, this displacement will be a limited one, and a new equilibrium will be established.

If an animal is repeatedly or continuously exposed to heat, the slip responses and compensatory responses are apt to be affected to different degrees. If the stress is relatively large, the slip responses tend to be the more markedly affected, so that the excess of slip over compensation, and thus the net displacement, is increased. The condition of the animal is then said to have deteriorated as a result of the repeated or continued stress. If, on the other hand, the stress is relatively mild, the compensatory will be more affected than the slip responses, with a corresponding diminution of net displacement. The condition of the animal is then said to have improved as a result of the repeated or continued stress. The former process is termed *deterioration*, the latter *acclimatization*.

If, between exposures to the severe conditions of the tolerance test, the animal is exposed to optimal conditions, the acclimatization feature may well become predominant; but if the conditions are hot, the effect may well be one of deterioration. If, on the other hand, the conditions between tests are cold, deacclimatization may occur, with a corresponding increase in the reaction to a given heat stress. Variations in reaction to a fixed heat test with both seasonal and shorter term fluctuations in holding conditions, have been seen in numerous animal experiments (Lee, unpublished data). They are understandable in these terms and the results reported here are particularly illustrative of this explanation.

The marked increase of reaction in the winter months (figure 1) corresponds to the postulated effects of deacclimatization. The succeeding minimum reaction occurs in the late spring and early summer when external conditions between tests are optimum. The rise of response as summer progresses is explicable as the deteriorating effect of external conditions which are relatively hot. The smallness of the minimum between summer and winter maxima may be explained as due to a slow recovery from the displacement set up by the long-

continued summer exposure—i.e. that recovery from deterioration is slower than recovery from deacclimatization.

It is interesting to note in this connection that evidence is accumulating (Schein, unpublished results) that the long-continued warm to hot conditions of Louisiana brings about a perpetually lower heat tolerance in the Jerseys, and a perpetually higher heat tolerance in the Jersey-Sindhi crosses. Many factors, and notably the physiological makeup of the animal itself, determine whether continued exposure to a given stress will result in acclimatization or in deterioration.

Repeatability of Respiratory Rate Responses

When the observations on respiratory rate are subjected to the same sorting, the repeatability coefficients obtained are much lower

TABLE 3. REPEATABILITY [1] OF MEAN RESPIRATORY RATE RESPONSES [2] OF HEIFERS (8–22 MONTHS) TO A STANDARD TEST HOT ATMOSPHERE (6 HRS. AT 105° F. AND 34 MM. Hg V.P.)—SORTED BY SEASON

	Apr.–July	Aug.–Sept.; Feb.–Mar.	Oct.–Jan.
	(low)	(high)	(intermediate)
Jerseys	0.47*	—0.28	0.65**
Sindhi-Jersey crosses	—0.08	0.05	0.29

* Significant at the 5% level.
** Significant at the 1% level.
[1] Coefficient of intra-animal correlation.
[2] Trapezoidal mean for a period of six hours' exposure.

and less significant (table 3). This is not surprising in view of the results reported in a previous paper (McDowell, Lee, Fohrman and Anderson, 1953). It is shown there that, under hot conditions, the respiratory rate is not very highly correlated with the respiratory volume, which is the important feature of respiratory cooling. The rate, moreover, is not significantly correlated with the rectal temperature under these conditions. Respiratory rate is subjected to too many and various influences to be dependable as a measure of thermal strain.

Summary

Jersey and Sindhi-Jersey crossbred cows were subjected for six hours to a standard hot atmosphere (105° F., and vapor pressure 34 mm. Hg) at repeated intervals of two months or longer, and

observations made on rectal temperature and respiratory rate. Between tests the animals were kept in the barn or on pasture under climatic conditions prevailing at Beltsville, Maryland.

The rectal temperature responses are found to vary markedly with the time of year. The responses show a maximum in February, and a smaller maximum in August, with a minimum in May–June.

Repeatability coefficients for the rectal temperature responses in heifers (8–22 months of age) remain fairly low until the responses are sorted into three seasonal groups: April–July (low); August–September and February–March combined (high); and October–January (intermediate). They then reach high and satisfactory levels.

The results are explained in terms of two sets of response to stress—yield or slip responses, the compensatory responses—which are differentially affected by the seasonal conditions (hot, temperate, cold) under which the animals live between tests.

Repeatability coefficients for respiratory rate responses to the test hot atmosphere remain low, even after seasonal sorting.

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SERUM ALKALINE PHOSPHATASE ACTIVITY IN EUROPEAN AND BRAHMAN BREEDS OF CATTLE AND THEIR CROSSBRED TYPES[1]

H. O. KUNKEL, DAVID K. STOKES, JR., W. B. ANTHONY[2] and MARY F. FUTRELL

Texas Agricultural Experiment Station

IN studies at this laboratory there has been a search for biochemical and physiological characteristics which might serve as indexes to individual variation in efficiency of feed utilization in beef animals (Kunkel, Colby and Lyman, 1953), in milk production, and in heat tolerance of cattle. Results obtained with rats have indicated that the serum alkaline phosphatase activity reflects both the nutritional state (Tuba and Madsen, 1952; Jackson, 1952) and the results of the administration of pituitary hormones (Li, Kalman and Evans, 1947). Thus it was of interest to determine the serum alkaline phosphatase activity in beef animals of feed-lot age and dairy animals of various ages.

Early in these studies it became evident that the levels of serum alkaline phosphatase activity were higher in the Brahman or Indian cattle *(Bos indicus)* than in the European breeds of cattle *(Bos taurus)*. The present work was undertaken as a detailed study of the extent of these differences and to gain some information concerning the physiological significance of the variation in serum alkaline phosphatase activity.

Experimental Procedure

A total of 299 animals were used in this study. The European breeds included Angus, Hereford, Jersey and Holstein. The Brahman or Zebu cattle used in this study were considered as one breed, since the Indian breed origins were obscure with most of the animals. Crossbred types included Brahman-Hereford first generation crosses,

[1] This investigation was conducted in cooperation with the Bureau of Animal Industry, United States Department of Agriculture, as a part of the Southern Regional Beef Cattle Breeding Project S-10 and the Texas Project of the Southern Regional Dairy Cattle Breeding Project S-3. The cooperation of Mr. Thomas C. Cartwright and Dr. B. L. Warwick of the Bluebonnet Farm, and of Dr. R. R. Shrode of the Department of Genetics, Texas Agricultural Experiment Station, in obtaining some of the blood samples is gratefully acknowledged.

[2] Present address: Department of Animal Husbandry and Nutrition, Alabama Polytechnic Institute, Auburn, Alabama.

[3] Departments of Biochemistry and Nutrition, Animal Husbandry and Dairy Husbandry, College Station, Texas.

Brahman-Jersey first generation crosses, Santa Gertrudis (developed from a cross between Shorthorn and Brahman cattle) and Charbray (developed from crosses between Charolaise and Brahman cattle). The beef type animals were feed lot animals given an adequate growing ration, while the dairy type animals were maintained on pasture with supplemental feeding.

The serum alkaline phosphatase activities were determined by the method of Bessey, Lowry and Brock (1946) using the procedure with 0.1 ml. of serum. This method utilizes para-nitrophenyl phosphate as the substrate. A study of the adaptability of this method for use with bovine sera demonstrated that the pH and substrate concentration optimum for use with human sera were also optimum for the estimation of bovine serum alkaline phosphatase. All phosphatase activities are reported in micromole units per liter of serum.

The blood samples were collected by venepuncture and allowed to clot. When samples were collected at the field laboratories, the clotted samples were stored at 0–5° C. until they could be brought into the biochemical laboratory for processing. The sera were separated by centrifugation and stored at —10° C. until analyzed. Studies on the stability of the phosphatase indicated no detectable loss of enzyme activity from such a procedure with storage as long as 14 days. This procedure allowed the collection of samples at substations not located at College Station.

Results and Discussion

Since the bovine serum alkaline phosphatase activity decreases with age, the animals were divided for purposes of comparison into 3 age groups: 8–14 months, 17–26 months and 3–9 years. Within these age groups there was no significant correlation between age and phosphatase level. All the beef type animals tested fell into the 8–14 months age group.

Analysis of variance (table 1) disclosed that breed and crossbred-type differences in phosphatase levels were statistically significant in young heifers, bulls and steers, in the older heifers, and in the aged cows.

The average serum alkaline phosphatase activities are given for each breed or crossbred type in table 2. It is to be noted that in the 8–14 months age group, the average phosphatase levels of the European breeds fell within a relatively small range of 3.07 to 3.61 micromole units per l. of serum. In the European breeds, within sexes, there

were no significant differences between the various breeds or between the beef or dairy types. The phosphatase levels of the Brahman calves were nearly twice the level of the European breeds, a difference which is highly significant statistically. A similar situation existed with the aged cows, in which the Brahman cows had significantly higher levels of phosphatase than did the Jerseys or the Holsteins.

In view of these differences it is particularly interesting to note the phosphatase activities in sera taken from animals resulting from a

TABLE 1. ANALYSIS OF VARIANCE OF SERUM ALKALINE PHOSPHATASE LEVELS

		Heifers or cows		Bulls		Steers	
Age group	Source of variation	D/f	Mean Square	D/f	Mean Square	D/f	Mean Square
8–14 months	Total	89		83		35	
	Breeds and crosses	6	46.48**	4	45.75**	1	10.34**
	Individuals	83	2.13	79	1.85	34	1.13
17–26 months	Total	38					
	Breeds and crosses	2	5.17*				
	Individuals	36	1.21				
3–9 years	Total	49					
	Breeds	2	9.92**				
	Individuals	27	0.86				

* Indicates significance at 5% level.
** Indicates significance at 1% level.

cross between the Brahman and a European breed. In all cases, the crossbreds demonstrated a phosphatase activity which was significantly higher than that in the European cattle and less than that in the Brahman cattle. This was true whether the crossbred was a first generation cross between the Brahman and the Hereford or Jersey, or the Santa Gertrudis. From limited data, it appears that Charbray cattle seem to follow the same pattern.

It is evident that the serum alkaline phosphatase level is controlled by heritable factors which differ in the European and Indian breeds of cattle. It also appears likely that the heritable variation in serum alkaline phosphatase is inherited in a strictly additive manner. The average of the 8–14 months old Hereford bulls and heifers was 3.52 micromole units per l. of serum and of Brahman bulls and heifers was 7.36 units per l. The average of these two values is 5.44 units per l., a value not greatly different from the average of 5.13 units per l. of serum found in the Brahman-Hereford crossbred bulls and heifers.

The variation of the phosphatase level within breeds is also of

interest. Although the wide range of phosphatase activities reported to occur in aged cows by Crookshank *et al.* (1952) was not observed in this study, the calculated coefficients of variation ranged from 11 to 34 percent in the younger animals, and from 39 to 49 percent in the cows 3–9 years of age (table 2). There was a greater coefficient

TABLE 2. AVERAGE LEVELS OF SERUM ALKALINE PHOSPHATASE IN EUROPEAN AND BRAHMAN BREEDS OF CATTLE AND SOME CROSSBRED TYPES

Age group	Breed origin	Breed or cross	Sex	Number of animals	Alkaline phosphatase	Coefficient of variation
					units/l. of serum	%
8–14 mo.	European	Angus	Bulls	12	3.44±0.17[1]	17.0
		Hereford	Bulls	36	3.63±0.14	23.3
			Heifers	23	3.35±0.20	28.3
			Steers	32	3.52±0.19	30.9
		Jersey	Heifers	10	3.07±0.24	24.2
		Holstein	Heifers	9	3.61±0.29	24.3
	Indian	Brahman	Bulls	24	6.85±0.41[2]	33.8
			Heifers	15	8.17±0.71[2, 3]	29.6
	Crossbred	Santa-Gertrudis	Heifers	9	6.14±0.30[2, 3]	33.8
			Steers	4	5.23±0.29	21.2
		Charbray	Bulls	3	4.23±0.28	14.9
			Heifers	3	5.60±1.14	11.2
		Brahman-Hereford	Bulls	9	5.81±0.57[2]	11.6
		cross	Heifers	21	4.90±0.24[2]	22.3
17–26 mo.	European	Jersey	Heifers	14	2.37±0.23	34.1
		Holstein	Heifers	13	2.45±0.20	29.6
	Crossbred	Brahman-Jersey cross	Heifers	12	3.53±0.46[1]	45.8
3–9 years	European	Jersey	Cows	16	1.61±0.19	48.3
		Holstein	Cows	17	1.58±0.19	48.7
	Indian	Brahman	Cows	17	2.92+0.28[2]	38.6

[1] Means±standard error.
[2] Values significantly ($p<0.01$) greater than those of European breeds (*B. taurus*).
[3] Significantly greater than Brahman-Hereford cross heifers ($p<0.01$).
[4] Significantly greater than Jersey and Holstein ($p<0.05$).

of variation in the older Jersey, Holstein and Brahman females. This was apparently the result of relatively constant values for the absolute standard deviations of the phosphatase activities while the mean phosphatase activity decreased with age.

In an effort to study further the variation within a breed, observations were made on the repeatability of phosphatase activities in a group of 19 (12 Angus, 7 Herefords) individually fed bulls. Phosphatase activities were determined at the beginning and end of a 147 day feeding period with the initial age of the animals ranging from 9 to 14 months. The repeatability of phosphatase levels in these

animals was only 0.104. In a group of 19 (7–8 months old) Hereford steers in which phosphatase activities were measured at the beginning and end of a 60 day feeding period, a repeatability of 0.460 was calculated. This correlation is significant ($p<0.05$) but still it is relatively low. These data suggest that environmental factors greatly influence the serum alkaline phosphatase activities in the Hereford and Angus breeds.

An interesting indication concerning the physiological significance of the variation of phosphatase activities in beef type European breeds was obtained in the group of 12 Angus and 7 Hereford bulls described above. The correlation coefficient between the initial phosphatase level and subsequent feed lot gain was —0.19, however, the correlation coefficient between the phosphatase activities determined at the end of the feeding trial and the rate of gain during the trial was —0.56. This correlation was statistically significant ($p<0.05$). Correlation coefficients between the final phosphatase levels and feed efficiency (lb. gain per lb. feed) and the average feed intake per lb. of body weight during the last 30 days of the feeding period were —0.63 and —0.60 respectively. These values are highly significant ($p<0.01$). Thus, it appears that factors involved in feed utilization may also influence variation of the serum alkaline phosphatase. It should be noted here, however, that the serum alkaline phosphatase activity in rats bears a positive correlation with feed intake (Tuba and Madsen, 1952; Jackson, 1952) in contrast to the negative correlation indicated in the data obtained with cattle.

Summary and Conclusions

The alkaline phosphatase was determined in a total of 299 cattle using para-nitrophenyl phosphate as the substrate. The animals in this study included animals of the *Bos taurus* or European breeds, of the *Bos indicus* or Brahman breeds, and of some of their crosses. The following conclusions may be drawn:

1. The average of serum alkaline phosphatase activities of immature Brahman cattle is approximately twice that of the European breeds of the same age.

2. Crossbreds such as the offspring of crosses between the Brahman and the Hereford or Jersey, and the Santa Gertrudis breed have phosphatase levels which fall between the European and Brahman breeds.

3. Although the alkaline phosphatase activity of bovine serum

decreases with age, Brahman cattle continue to have the higher phosphatase levels.

4. Selection for dairy type as opposed to selection for beef type has little or no significant effect on the serum alkaline phosphatase. Sex has no marked effect.

5. Repeatability of the serum alkaline phosphatase within groups of Angus or Hereford bulls or Hereford steers is low, suggesting a considerable effect of environmental factors.

6. In Hereford and Angus bulls, the phosphatase level appears to be negatively correlated with factors affecting rate of gain, efficiency of feed utilization and feed intake.

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CORRELATIONS BETWEEN GRADES AND GAINS OF HEREFORD CATTLE AT DIFFERENT STAGES OF GROWTH AND BETWEEN GRADES AT DIFFERENT TIMES[1]

RALPH M. DURHAM and J. H. KNOX

New Mexico Agricultural Experiment Station[2]

BEEF cattle are commonly sold on the basis of grade, with marked price differential between grades of both feeder cattle and fat cattle. The price difference between grades of feeder cattle may reflect the feeder's idea that high grading calves will gain well in the feedlot and be high grading fat cattle. The price difference between slaughter grades probably reflects the packer's idea that high grading fat cattle have high dressing percentages and produce high grading carcasses.

This study was made to determine what associations, if any, exist between live grades of an animal at various stages of growth. It was also made to find what associations exist between an animal's grades and gains.

Materials and Methods

Part of the data comes from a group of 424 steers fed as long yearlings. Each fall for 13 years, 30 to 40 weanling steer calves were kept and run on the range until the following fall. These steers were calved from March to June, with a majority of them being calved in April. The calves were weaned, weighed and graded in October or early November. They were fed a small amount of cake for a short time following weaning, and thereafter were run on the range until the next fall, at which time they were brought in to the feedlots. The steers were graded again when they were put on feed, and just before they were shipped to market. Carcass grading was done by federal graders at the slaughterhouse. Simple correlations between the variables were calculated within sire and year.

Another group of 59 cattle was fed as post-weaning calves in a type-size study being made at this station. Data are included for 3 years. Feeder grades, feedlot gains, fat grades, and carcass grades

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TABLE 1. WITHIN SIRE AND YEAR CORRELATIONS BETWEEN VARIOUS VARIABLES FOR STEERS FED AS LONG YEARLINGS

	Yearling Gain	Yearling Grade	Feedlot Gain	Fat Grade	Carcass Grade
Calf grade	—.107	0.264**	—.021	0.234**	0.022
Yearling gain	....	0.083	0.173**	0.098	0.015
Yearling grade	....	....	—.006	0.229**	0.107*
Feedlot gain	....	....	....	0.464**	0.349**
Fat grade	....	....	....	....	0.436**

* Significant at 5% level.
** Significant at 1% level.

(by federal graders) were obtained on these cattle, which were fed 196 days. Correlations between the variables were calculated within type and year.

The live grades on both sets of cattle were assigned by a committee of graders, working individually. The average of the committee's grades was used as an estimate of grade. The grades were then given a numerical value—the higher number denoting the higher grade. It is thought that the points of emphasis in visual grading were typical of those used by others in grading cattle, although there is no analysis to show that this was true.

Results

Correlations are shown in tables 1 and 2.

The correlations between feeder grade at weaning and the other grades are not very high and tend to decline with each period, becoming virtually zero for the association between weaning grade and carcass grade.

The tendency for weaning grade to be negatively associated with

TABLE 2. WITHIN TYPE AND YEAR CORRELATIONS BETWEEN VARIOUS VARIABLES FOR STEERS FED AS POST-WEANING CALVES

	Feedlot Gain	Fat Grade	Carcass Grade
Calf grade	—.068	0.093	—.055
Feedlot gain	....	0.564**	0.254
Fat grade	....	....	0.364**

** Significant at 1% level.

succeeding gains is indicated by the correlations, although none was significant. Conversely, there is a strong tendency for gains in a particular period to be associated with grades at the end of that period. This is true for all the grades and periods. The correlations between yearling grade and feedlot gain and between calf grade and feedlot gain are virtually zero, but the correlations between feedlot gain and fat grade for yearlings and calves were 0.46 and 0.56, respectively, both being relatively high and statistically significant. Fat grade is correlated with carcass grade—0.44 for the long yearlings and 0.36 for the calves. The small, but significant, correlation between yearling grade and carcass grade indicates positive association between these two variables.

Discussion

Hultz (1927) found a correlation of 0.218 between fat grade and feeder grade. His correlation between feeder grade and carcass grade was 0.234, and the correlation between fat grade and carcass grade was 0.477. Carcass grading in 1927 may not be comparable with grading now. Stanley and McCall (1945), working with calves, found a low (0.02) and insignificant correlation between feeder grade and carcass grade. They also found low and insignificant negative correlations between feeder grade and daily gain in the feedlot.

The data presented here agree with those of Stanley and McCall (1945), both with regard to the association of feeder grade with subsequent gain, and feeder grade with carcass grade. The data are also consistent with those of Hultz (1927) with regard to the association between fat grade and carcass grade.

The explanation for the lack of correlation between calf grade and carcass grade may be that the standards for grading are different. Feeder grade is as nearly independent of condition as possible, but fat grade is largely determined by it and carcass grade almost completely so.

Unpublished data from this station indicate that compact type calves consistently grade higher than large type cattle at weaning time but not as fat cattle or carcasses. Knox and Koger (1946) found that, when yearlings were fed, the compact cattle did not have higher fat grades or carcass grades than the large cattle. Actually, the large cattle had a slightly higher mean fat grade. Compactness is one of the important criteria of calf grade, and that may be part of the reason for a lack of correlation between calf grade and carcass grade.

Grading calves largely on the basis of conformation and compactness and carcasses largely on the basis of finish might be expected to result in no association between the two grades. If this is true, the breeder and the packer should get together.

The slight tendency for initial grade to be negatively associated with gain on feed may also be explained on this basis. Compact cattle have consistently gained slower than large cattle (Knox and Koger, 1946). As long as the compact cattle are graded higher than the large type cattle, the negative association of grade with subsequent gain is to be expected.

Since greater perfection in body form as estimated in weanling calves does not lead to higher carcass grades, greater emphasis in breeding should be placed on characteristics such as cow productivity and feedlot efficiency. The fact that the gains made on feed were associated to a greater degree with succeeding grades than with previous grades accentuates this point. Cattle that graded high at the beginning of the feeding period were not necessarily fast gainers, but fast gaining cattle tended to grade high at the end of the feeding period.

Summary

Correlations between grades and gains of Hereford cattle at various stages of growth have been obtained. The study included 424 steers from 68 bulls, fed out during a 13-year period, and 59 calves representing two different types of cattle fed out over a 3-year period.

Grade at the beginning of a period tended to be negatively associated or not associated at all with the subsequent gain.

Gain during the fattening period was associated with the subsequent grade.

Yearling grade had a low, but significant, association with carcass grade.

No correlation exists in these data between weaning grade and carcass grade. Possible explanations for this lack of association are presented.

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RELATIONSHIPS BETWEEN MEAT PRODUCTION CHARACTERS AND BODY MEASUREMENTS IN BEEF AND MILKING SHORTHORN STEERS

T. S. YAO,[1] W. M. DAWSON [2] and A. C. COOK [2]

U. S. Department of Agriculture

BODY conformation in cattle is one of the important bases in judging and selecting animals for breeding and production purposes. Measurements taken on various parts of the body furnish an objective description of body conformation. The ability of cattle to produce meat could be estimated with these measurements if relationships between body measurements and meat production characters were obtained. A number of studies have been made on the relations of certain body measurements to some of the performance factors of steers, such as Black, Knapp and Cook (1947) the correlations of body measurements with rate of gain and certain carcass characteristics; Cook, Kohli and Dawson (1951) relationships of five body measurements to slaughter grade, carcass grade and dressing percentage; Dawson, Phillips and Black (1947) birth weight and growth of steers; Hankins and Burk (1938) relationships among production and grade factors of beef; Hultz and Wheeler (1927) type of beef steers; Kohli, Cook and Dawson (1951) relations between some body measurements and certain performance characters; Knapp and Cook (1933) comparisons of body measurements; Lush (1928, 1932) the change of body measurements and the relations of body shape to the rate of gain and dressing percentage; Severson, Gerlaugh and Bentley (1917) body measurements and gain of steers; and Willard (1948) birth weight and weight gain. Since the characters studied varied, the conditions under which the studies were made were not all the same and the results differed somewhat, there is a need for further studies.

[1] Guest research scientist from China.

[2] Animal Husbandman, U. S. Department of Agriculture.

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This study is based on nineteen body measurements taken on foot immediately before slaughter, and eight meat production characters of 163 steers. Relationships between meat production characters and body measurements as well as relationships among the body measurements were studied. The comparisons of the importance of the measurements were made in order to select a part of them to represent the nineteen measurements.

Materials and Methods

The data used in this study were from 101 beef Shorthorn and 62 Milking Shorthorn steers. These steers were the offspring of 18 and 10 sires respectively. They were raised at the Beltsville Research Center from 1940 to 1950. All the animals were nursed until they reached 500 pounds live weight and then were fed individually in a record of performance test to a live weight of 900 pounds when they were slaughtered. During the feeding period the animals received a mixture consisting of cracked yellow corn 5 parts, ground oats 3 parts, wheat bran 1 part, and linseed meal with 31 percent protein 1 part by weight, with a total digestible nutrients of 75.5 percent and a total digestible protein of 10.57 percent. No. 2 leafy alfalfa hay was given to the steers at the rate of approximately 1 pound of hay to every 2 pounds of concentrate. Concentrate was full fed to the steers and none of the animals had access to pasture.

Nineteen body measurements of each steer were taken on foot immediately before slaughter (figure 1). The body measurements were taken by the same person in triplicate and averaged in order to eliminate as much as possible the variations caused by changes in the position of the animal. Birth weight, number of days to weaning, number of days to final weight, efficiency of feed utilization, average daily gain, slaughter grade, carcass grade, and dressing percentage of the steers were regarded as the meat production characters. Efficiency of feed utilization was expressed as pounds of gain per 100 pounds of total digestible nutrients consumed during the feeding period. Slaughter grade and carcass grade were the average of scores made by three members of a committee who were familiar with the standard grades of steers adopted by the U.S.D.A. The carcasses were graded after cooling for 72 hours. Dressing percentage was obtained by dividing the cold carcass weight by the live weight of the steer taken immediately before slaughter.

The methods described by Snedecor (1948) for calculating simple

and multiple correlation coefficients and determining their significance were used in this study. Variances and covariances caused by breed differences were calculated and subtracted from the total variances and covariances for the characters and measurements.

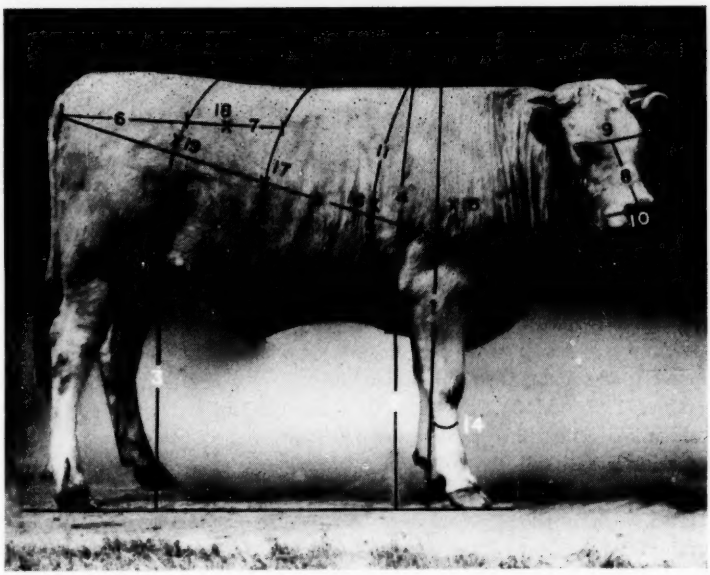

Figure 1. Milking Shorthorn steer showing location of measurements taken: 1. Height at withers; 2. Height at floor of chest; 3. Height at rear flank; 4. Depth of chest; 5. Length of body; 6. Length of rump; 7. Length of coupling; 8. Length of nose; 9. Width between eyes; 10. Width of muzzle; 11. Circumference at fore flank; 12. Circumference at navel; 13. Circumference at rear flank; 14. Circumference at shin bone; 15. Width at shoulder; 16. Width at chest; 17. Width at paunch; 18. Width at loin; and 19. Width at hips. Width measurements 15 through 19 were taken at the points marked x.

Results and Discussion

The eight meat production characters and nineteen body measurements could be divided on the basis of their relationships and correlations into eight main groups and two subgroups as follows:

Group 1. Growth characters:

Subgroup 1. Age characters: Birth weight, days to weaning, days to final weight.

Subgroup 2. Growth rate: Days to final weight, efficiency, average daily gain.

Group 2. Beef characters: Slaughter grade, carcass grade, dressing percentage.

Group 3. Height measurements: Height at withers, height of chest floor, height at flank, depth of chest.

Group 4. Length measurements: Length of body, length of rump, length of coupling.

Group 5. Head measurements: Length of nose, width between eyes, width of muzzle.

Group 6. Width measurements: Width at shoulder, width at chest, width at last rib, width at loin, width at hip.

Group 7. Circumference measurements: Circumference at fore flank, circumference at navel, circumference at rear flank.

Group 8. Shin bone measurements: Circumference at shin bone.

Correlation coefficients between the characters or measurements within each group were in general significant but the correlations between the characters or measurements of different groups varied (tables 1, 2 and 3). The growth characters formed the first group and were divided into two subgroups. Days to final weight was highly correlated with all the other four characters in the first group and was put in both subgroups. A heavier birth weight was closely associated with a shorter period to reach 500 pounds weaning weight and 900 pounds final weight, and the number of days to weaning was positively and highly correlated with the number of days to final weight. Kohli *et al.* (1951) obtained a similar result for 157 Milking Shorthorn steers of which 62 animals were also used in this study. The results obtained by Dawson *et al.* (1947) working with beef Shorthorn steers showed similar relations between birth weight and the subsequent growth to 500 pounds and to the growth from birth to 900 pounds of body weight. However, they found no relation between the number of days from birth to 500 pounds and the number of days from 500 pounds to 900 pounds. The number of days to final weight was closely associated in a negative way with the efficiency of feed utilization and with average daily gain. A high positive correlation coefficient existed between average daily gain and the efficiency of feed utilization. This indicates that the greater the daily gain of the animals the less the time required and the smaller the amount of feed needed to reach the final body weight for slaughter. Kohli *et al.* (1951) obtained similar results with Milking

TABLE 1. CORRELATION COEFFICIENTS BETWEEN GROWTH RATES, BEEF CHARACTERS AND BODY MEASUREMENTS IN BEEF AND MILKING SHORTHORN STEERS

Item	Birth weight	Days to weaning	Days to final weight	Efficiency	Daily gain	Sl. grade	Carcass grade	Dressing percentage
Growth rates:								
Birth weight	——							
Days to weaning	—.40**							
Days to final weight	—.39**	.69**						
Efficiency	.130	—.15	—.72**					
Daily gain	.19*	—.06	—.77**	.84**				
Beef characters:								
Slaughter grade	—.11	—.01	—.05	.05	.08			
Carcass grade	—.18*	—.01	—.04	.02	.08	.70**		
Dressing percentage	—.13	.14	.17*	—.24**	—.09	.30**	.47**	
Height measurements:								
Height at withers	.09	.03	—.03	.01	.09	—.28**	—.31**	.01
Height at floor of chest	.20*	—.03	—.09	.09	.12	—.41**	—.32**	—.12
Height at flank	.02	.08	.11	—.08	—.05	—.29**	—.12	.07
Depth of chest	—.07	.08	.18*	—.19*	—.16*	—.05	.06	.18*
Length measurements:								
Length of body	.30**	.02	.03	—.06	.03	—.03	.10	.11
Length of rump	.09	—.19*	—.13	.03	.05	—.16*	—.09	—.03
Length of coupling	.03	—.11	—.05	.00	.00	.00	.17*	—.04
Head measurements:								
Length of nose	.02	.18*	—.11	—.05	—.02	—.03	.02	.02
Width between eyes	—.05	—.02	.14	—.10	—.18*	—.01	.06	.10
Width of muzzle	.07	—.06	.03	—.11	—.07	—.06	.03	.10
Width measurements:								
Width at shoulder	—.14	—.14	—.05	—.06	—.07	.12	.16*	.21*
Width at chest	—.20*	—.07	.05	—.12	—.09	.10	.10	.16
Width at last rib	—.04	—.08	—.02	.00	—.02	.17*	.17*	.02
Width at loin	—.02	—.09	.01	.08	—.04	.13	.15	.11
Width at hip	—.13	—.05	—.02	.00	.02	.05	.17*	.08
Circumference measure:								
Circ. fore flank	—.15	.03	.18*	—.27**	—.20*	.14	.22**	.42**
Circ. at navel	01	—.05	—.03	—.02	.05	.29**	.27**	.06
Circ. at rear flank	.07	—.12	.06	—.21**	—.09	.18*	.29**	.27**
Shin bone measurement:								
Circ. at shin bone	.16*	—.08	.02	—.07	—.01	—.03	—.11	—.12

n=163.
Significance level 1%=.208**.
5%=.159*.

TABLE 2. CORRELATION COEFFICIENTS BETWEEN BODY MEASUREMENTS IN BEEF AND MILKING SHORTHORN STEERS

Item	Height at Withers	Height Chest Floor	Height at Flank	Depth Chest	Length Body	Length Rump	Length Coupling	Length Nose	Width between Eyes	Width Muzzle
Height measurements:										
Height at withers										
Height at floor chest	.75**	...	...	...	...	...	...	...	...	...
Height at flank	.61**	.61**	...	...	...	...	...	...	...	...
Depth of chest	.32**	—.01	.08	...	...	...	...	...	...	...
Length measurements:										
Length of body	.25**	.12	.27**	.07	...	...	...	...	...	...
Length of rump	.12	.13	.16	.12	.28**	...	...	...	...	...
Length of coupling	.09	.02	.14	.01	.26**	—.02	...	...	...	...
Head measurements:										
Length of nose	.22**	.09	.15	.06	.15	.04	.06	...	...	...
Length between eyes	.05	—.05	.08	.17*	.19*	.05	.11	.17*	...	...
Length of muzzle	.16*	—.04	.07	.21**	.23**	.18*	.07	.17*	.27**	...
Width measurements:										
Width at shoulder	—.20*	—.21**	—.08	—.01	.19*	.33**	.12	—.02	.10	.13
Width at chest	—.04	—.13	—.07	.12	—.01	.34**	.08	—.01	.07	.10
Width at last rib	—.02	—.15	—.06	.01	.16*	.23**	.15	.00	—.03	.16
Width at loin	—.04	—.05	—.05	.01	—.01	.16	.00	—.08	.20*	.10
Width at hip	.18*	.14	.17*	.06	.13	.37**	.11	—.06	—.10	.07
Circumference measurements:										
Circ. at fore flank	.17*	—.18*	.02	.61**	.04	.07	.04	.05	.28**	.28**
Circ. at navel	—.01	—.17*	—.07	.21*	.07	—.06	.18*	.00	.09	.11
Circ. at rear flank	.27**	.06	.21**	.25**	.20*	.24**	.18*	.12	.18*	.28**
Shin bone measurements:										
Circ. at shin bone	.07	.06	.22**	—.01	.10	—.03	.11	.03	.15	.08

n=163.
Significance level 1%=.208**.
5%=.159*.

TABLE 3. CORRELATION COEFFICIENTS BETWEEN BODY MEASUREMENTS IN BEEF AND MILKING SHORTHORN STEERS

Item	Width at Shoulder	Width Chest	Width Last Rib	Width Loin	Width at Hip	Circ. Fore Flank	Circ. Navel	Circ. Rear Flank	Circ. of Shin Bone
Width measurements:									
Width at shoulder	...	...	...	...	...	...	...	...	...
Width at chest	.72**	...	...	...	...	...	...	...	...
Width at last rib	.36**	.42**	...	...	...	...	...	...	...
Width at loin	.24**	.30**	.38**	...	...	...	...	...	...
Width at hip	.43**	.52**	.48**	.30**	...	...	...	...	...
Circumference measurements:									
Circ. at fore flank	.22**	.33**	.19*	.00	.01	...	...	...	...
Circ. at navel	.10	.19*	.69**	.12	.17*	.47**	...	...	...
Circ. at rear flank	.17*	.23**	.45**	.14	.31**	.14	.63**	...	...
Shin bone measurement:									
Circ. at shin bone	.11	.04	.17*	—.03	.15	—.04	.09	.10	...

n=163.
Significance level 1%=.208**.
5%=.159*.

Shorthorn steers. All the three beef characters were highly correlated with each other. The indication was that the scores of live steers graded on foot before slaughter could be used to predict their carcass grades fairly well and to a lesser extent their dressing percentages which can be obtained only after slaughter. Using carcass grade to predict dressing percentage would be more precise than using slaughter grade as there existed a somewhat higher correlation between carcass grade and dressing percentage, but it would, of course, not be as useful since if the animals are killed dressing percentage can be obtained directly.

Height at withers was highly correlated with all the three other characters in the height measurement group and is the best single measurement to represent this group of measurements. However, depth of chest was not correlated with height at floor of chest and height at flank in this group. Length of body in the length measurement group was significantly correlated with the other two length measurements. There was no correlation between the length of rump and the length of coupling. The three head measurements were moderately correlated to each other. The characters in the width measurement group were all highly correlated with each other and the width at chest was the best measurement to represent the group. In the circumference group the circumference of navel was the best one to represent the whole group of measurements as there was no correlation between the circumference at fore flank and the circumference at rear flank. The last group consisted of one character only, the circumference at shin bone, which was significantly correlated with height at flank.

Growth characters were irregularly correlated with the characters in the other groups. A steer with a heavier birth weight tended to have a poorer slaughter grade, carcass grade and dressing percentage than one with a lighter birth weight. On the contrary, a steer with a longer period from birth to weaning and to final weight tended to have a better dressing percentage than one with a shorter nursing or feeding period. The growth characters were for the most part negatively correlated with the width measurements but not significantly except for the correlation between birth weight and width of chest. The higher the birth weight, the narrower the width of chest would be. Birth weight was positively correlated with height at floor of chest, length of body, and circumference at shin bone. The small negative correlations between growth rate characters and head measurements indicate a slight tendency for animals with smaller heads

to have faster growth than those with larger heads. This is not at all conclusive since the correlations are small and most of the correlations were not significant. The negative correlations between the growth rate characters and circumference measurements also showed that those animals with a smaller circumference would have a better growth rate (efficiency of feeds utilization and average daily gain) than those with a larger circumference. Efficiency was also negatively correlated with dressing percentage so that a faster growing steer would have a poorer dressing percentage. The trend seems opposite to the general assumption but it must be remembered that all of these steers weighed approximately 900 pounds when measured.

Beef characters had a general trend of positive correlation with all the width and circumference measurements. Slaughter grade was negatively correlated with all the height, length and head measurements. Carcass grade was also negatively correlated with most of the height measurements. Cook *et al.* (1951) obtained similar results in Milking Shorthorn steers. Knapp *et al.* (1933) obtained similar results and selected heart girth, width at chest, and width at shoulder as indices for the fleshing of steers.

All the height measurements were positively correlated with all the length measurements although not all were significant. They could be regarded as one group of measurements which indicated the size of the animal. They were all negatively correlated with beef characters and could be called non-meat-production measurements or skeletal measurements as Knapp *et al.* (1933) and Cook *et al.* (1951) did. All the width measurements were positively correlated with all circumference measurements and could be regarded as another group of measurements which indicated the thickness and heaviness of the beast and could be called fleshing measurements as Knapp did.

Considering the relations between birth weight and all the other characters and measurements, it seems that birth weight is somewhat similar to the skeletal characters. It was positively correlated with height at floor of chest, length of body, and circumference at shin bone, but negatively correlated with all the width measurements which indicated the amount of meat production of steers. Birth weight was also negatively correlated with all the beef characters.

Depth of chest was not correlated with height at floor of chest and height at flank in the same height measurement group, but it was significantly correlated with all the three circumference measurements. This measurement might therefore be regarded as a measure-

ment in the circumference measurement group. Height of flank was the only measurement significantly correlated with circumference at shin bone. In the length measurement group, length of rump was not correlated with length of coupling but it was correlated with all the width measurements. Therefore this measurement might be included in the width measurement group.

Multiple correlation coefficients for beef characters with those body measurements which were most closely related to these characters were as follows:

$R_{s.236}$=.4838	1% significance level=.244
$R_{c.17}$=.4942	1% significance level=.208
$R_{d.45}$=.4357	1% significance level=.208

s=slaughter grade, c=carcass grade, d=dressing percentage, 1=height at withers, 2=height at floor of chest, 3=length of rump, 4=width at shoulder, 5=circumference at fore flank, 6=circumference at navel, 7=circumference at rear flank.

All the above multiple correlations were highly significant. It is believed the addition of more independent variables would not increase the size of these multiple correlations appreciably. Indices for the evaluation of beef characters could therefore be obtained by the following formulas in which the related body measurements with positive simple correlations to the characters were used as numerators and those with negative correlations as denominators:

$$\text{Index, slaughter grade} = \frac{\text{circumference at navel}}{\text{height at floor chest} \times \text{length of rump}}$$

$$\text{Index, carcass grade} = \frac{\text{circumference at rear flank}}{\text{height at withers}}$$

Index, dressing percentage=width at shoulder×circumference at fore flank

A general index for the relationship between beef characters and body measurements could be expressed with the following formula:

$$\text{Index for beef character} = \frac{\text{width} \times \text{circumference}}{\text{height} \times \text{length}}$$

This formula would be an aid in the selection of animals especially in connection with a long time breeding program even if the multiple correlation figures obtained were not large enough to make a very accurate prediction for meat production.

Black *et al.* (1938) and Lush (1928) found high correlations between body measurement-ratios and slaughter grade, dressing percentage, and fatness of steers when the ratios were expressed in the same

way as in the above formula, but low correlations when the ratios were expressed in other ways. Knapp *et al.* (1933) suggested that the ratio of heart girth and height at withers could be regarded as an expression of the amount of meat on the animals.

Black *et al.* (1938) and Lush (1932) worked on cattle of different breeds and obtained higher correlations than the correlations studied in this paper. A possible reason for the high correlations in their results is that the variances and covariances caused by breed differences were not eliminated in their calculations. As breed differences were one of the important factors in the present study they could bring about a great amount of variance and covariance in the data.

Summary

Data of eight meat production characters and nineteen body measurements from 101 beef Shorthorn steers and 62 Milking Shorthorn steers raised at the Beltsville Agricultural Research Center were used to study realtionships between these characters and the measurements. Since the material was from two different breeds, the variance and covariance caused by breed differences were calculated and subtracted from the total variances and covariances to increase the homogeneity of the data.

All the eight meat production characters and nineteen body measurements were divided into eight main groups and two subgroups. Characters or measurements within each group or subgroup were in general well correlated with each other. Each body measurement group could be represented fairly well by one measurement which was highly correlated with all the other measurements within the group. Height at withers was the best for the height measurement group, length of body for the length measurements, width of muzzle for the head measurements, width at chest for the width measurements, and circumference at navel for the circumference measurements. Depth of chest was well correlated with all the circumference measurements and could be included in the circumference group instead of the height group. Length of rump could be included in the width group rather than the length group.

All the width and circumference measurements were positively correlated with slaughter grade, carcass grade and dressing percentage, and could be called fleshing measurements. All the height and length measurements were negatively correlated with slaughter grade and could be called skeletal measurements. Birth weight had positive correlations with most of the height and length measurements but negative

correlations with the width measurements. It was thus similar to the skeletal measurements. A higher birth weight tended to go with less days to weaning, less days to final weight and poorer beef characters, but it also tended to go with a greater daily gain and higher efficiency in feed utilization than a lower birth weight.

Measurements of head, width and circumference had negative correlations with efficiency of feed utilization and average daily gain. This indicated that a steer with a small head, narrow body and small body circumference would have a better efficiency and daily gain when all steers were measured at 900 pounds than one with a larger head, wider body and larger body circumference.

Significant multiple correlations between the beef characters and some body measurements were obtained. Formulas for calculating indices for the beef characters were derived on the basis of the relationships between the beef characters and their closely correlated body measurements.

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VALUE OF UREA NITROGEN IN RATIONS CONTAINING DIFFERENT CARBOHYDRATE FEEDS[1]

MARVIN C. BELL,[2] WILLIS D. GALLUP and C. K. WHITEHAIR

Oklahoma Agricultural Experiment Station[3]

IN order to make most efficient use of urea as a nitrogen supplement to poor-quality roughage in ruminant rations, a certain amount of concentrate feed containing readily available carbohydrate appears necessary. Presumably, the carbohydrate provides an available source of energy and of the carbon fragments required for synthesis of amino acids from urea nitrogen by the rumen microorganisms. A still larger amount of carbohydrate may be necessary, depending on the roughage fed, to meet the energy requirements of the animal itself and to prevent undue wastage of protein in metabolism. Carbohydrate availability, therefore, is an important consideration in determining the usefulness of urea in certain rations. Although Mills and associates (1942, 1944) reported that starch and the cereal grains were more desirable than sugar (molasses) as a source of carbohydrate in urea-containing rations, the relative value of different grains and high energy feeds is a question frequently raised by the practical feeder. Detailed discussion relating to the carbohydrate component of urea rations is to be found in comprehensive reviews by McNaught and Smith (1947) and Owen (1951) and in recent papers by Arias *et al.* (1951) and Pierce (1951).

The present investigation was designed to determine by nitrogen balance procedures the comparative value of some common carbohydrate feeds in promoting efficient utilization of urea nitrogen by steers.

Experimental

The feeds selected for comparison were: ground yellow corn, rolled barley, ground milo, shredded dehydrated sweet potatoes, blackstrap molasses, and a combination of corn and molasses. Each of these feeds was used as the principal source of carbohydrate in low-protein rations, alone, and supplemented with equal amounts of urea.

The sweet potatoes were shredded and dried with forced heat in a

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[2] Present address, University of Tennessee, Knoxville, Tennessee.

[3] Departments of Animal Husbandry and Agricultural Chemistry Research.

mechanical dehydrator similar in design to an alfalfa dehydrator. There was some scorching in the process but not to the extent that it impaired palatability. The composition of the product on a dry matter basis was: protein, 6.6 percent; ether extract, 0.9; crude fiber, 4.0; and nitrogen-free extract, 83.3. The other feeds were of average quality and their composition is well known. Urea was fed as "Two-Sixty-Two," a commercial preparation for feeding purposes, having a nitrogen content of 42 percent. Locally grown prairie hay was the source of roughage in the rations and additional minerals were supplied by bonemeal and salt.

Three experiments, each consisting of a series of nitrogen-balance trials, were conducted in consecutive years with yearling Hereford steers weighing 650 lb. in the first experiment and Hereford steer calves weighing 500 lb. in the second and third experiments. The equipment used and general methods of procedure have been described in previous papers (Gallup, Briggs and Hatfield, 1950).

Each balance trial was of 20 days' duration, during which time each steer was fed twice daily a constant amount of one of the rations under comparison. In one trial of the second experiment, however, all steers received the same ration (soy bean oil meal) at the same time. Four steers were used in the trials of the first experiment and six in the trials of both the second and third experiments. Feces and urine were quantitatively collected during the last 10 days of each trial. The feces were caught in specially constructed gutter boxes and transferred by an attendant to tightly covered metal containers. They were weighed daily, mixed, and 2 percent aliquots preserved with thymol in sealed glass jars at 0° C. Nitrogen was determined on the combined aliquots previous to their being dried for other chemical analysis. Urine was collected by means of rubber funnels which were strapped to the steers and connected by hose to 3-gal. bottles below the false bottom of the metabolism stalls. Urine collections were acidified with HCl and 2 percent aliquots were preserved at 0° C. for nitrogen determination.

Corn and sweet potato rations were compared in the first experiment; corn, barley and milo in the second; and corn, corn-molasses, and molasses in the third. The protein content of the rations compared in each experiment was adjusted to 7–8 percent with oil meal and then raised to a level of 10–12 percent protein equivalent by addition of equal amounts of urea. Thus, urea supplied approximately 30 percent of the total nitrogen in the supplemented rations. A ration

of barley and soybean oil meal, equivalent in protein to the urea-supplemented barley ration, was included in the second experiment for purposes of comparison. The composition of the rations is given in table 1. Results of all experiments were treated statistically by analysis of variance (Snedecor, 1946).

The biological value of nitrogen in the supplemented rations containing 10 percent or more of protein was calculated by the formula,

$$\frac{\text{Retained N}+\text{Metabolic N}+\text{Endogenous N}\times 100}{\text{Apparent digested N}+\text{Metabolic N}}$$

Metabolic nitrogen was estimated as 5.3 gm. per kg. dry matter eaten, and endogenous nitrogen as $0.712\ W^{0.42}$, body weight (W) being expressed in kg. (Swanson and Herman, 1943).

Results and Discussion

In the first experiment difficulty was encountered in keeping the steers on a constant feed intake; consequently, of the eight trials planned for each of the four rations in this experiment, only five were completed with the unsupplemented corn ration and six with the corn-urea ration. Eight or more trials were completed with each of the two corresponding sweet potato rations. Results of these trials, presented in table 2, show that the unsupplemented corn and sweet potato rations were similar with respect to digestibility of dry matter and N-free extract. There were significant differences between these two rations, however, in digestibility of both protein and crude fiber, these differences of 10.2 and 12.4 percentage units, respectively, being in favor of the corn ration.

Supplementation with urea increased the digestibility of nutrients in both rations, particularly the corn ration, but only the increase in digestibility of protein from 49.9 percent to 64.5 in the corn ration, and from 39.7 percent to 52.6 in the sweet potato ration, was statistically significant. The increase in digestibility of total dry matter to a value of 71.5 percent in the urea-supplemented corn ration, as compared to 67.2 percent in the corresponding sweet potato ration, affords some evidence of a more favorable effect of urea in rations based on corn than in those based on sweet potatoes.

Average daily nitrogen retention by steers on each of the two unsupplemented rations was only about 6 gm. per day. The increases in nitrogen retention effected by urea supplementation amounted to 11.1 gm. with the corn ration and 10.4 gm. with the sweet potato ration. These parallel increases were equivalent to about 50 percent

TABLE 1. DAILY AMOUNT AND PERCENTAGE COMPOSITION OF UNSUPPLEMENTED RATIONS[1]

Ration[2]	Experiment 1		Experiment 2				Experiment 3		
Designation Description	Corn	Sweet Potatoes	Corn	Barley	Milo	Barley Plus Meal	Corn	Corn and Molasses	Molasses
Ingredient (grams)									
Prairie hay	2000	2000	1800	1800	1800	1800	1800	1800	1800
Corn	3000	....	1730	....	....	....	1710	854	....
Sweet potatoes	....	2600	....	....	....	....	....	....	....
Barley	....	....	....	1800	....	1486	....	....	....
Milo	....	....	....	....	1736	....	....	....	....
Molasses	....	....	....	....	....	....	....	836	1670
Oil meal[3]	....	228	70	....	64	354	90	224	356
Bone meal	44	44	50	50	50	50	50	50	50
Salt	30	30	30	30	30	30	30	30	30
Total	5074	4902	3680	3680	3680	3720	3680	3794	3906
Dry matter	4511	4420	3366	3357	3362	3383	3338	3285	3230
Composition (percent)									
Organic matter	94.9	92.5	93.3	92.8	93.5	91.8	93.2	91.1	88.9
Protein	7.1	7.1	8.3	8.2	8.2	11.6	8.5	8.7	8.9
Ether extract	5.8	1.6	3.1	2.0	3.0	2.5	3.2	2.4	1.6
Crude fiber	15.1	16.6	18.3	19.8	18.1	19.6	19.0	19.0	19.1
N-free extract	66.9	67.2	63.6	62.8	64.2	58.1	62.5	61.0	59.3

[1] These rations were fed alone, and, with the exception of the barley plus meal ration, supplemented with 50 gm. of urea (Two-Sixty-Two) per day in experiment 1, and 45 gm. in experiments 2 and 3. "Two-Sixty-Two" is a commercial preparation of urea containing 42 percent nitrogen. It was supplied by E. I. duPont de Nemours and Company, Wilmington, Delaware.

[2] Ingredients are shown on an air dry basis; percentage composition is given on a dry matter basis.

[3] Cottonseed meal in experiment 1 and soybean oil meal in experiments 2 and 3.

TABLE 2. THE SUPPLEMENTAL VALUE FOR YEARLING STEERS OF UREA [1] ADDED TO CORN AND SWEET POTATO RATIONS

Ration Identification	Number of Trials	Daily Feed Intake			Nutrient Digestibility				Nitrogen Retained Daily	Biological Value of Nitrogen [2]
		Dry Matter	Protein (N×6.25)	Nitrogen	Dry Matter	Protein	Crude Fiber	N-Free Extract		
		gm.	%	gm.	%	%	%	%	gm.	%
Corn	5	4511	7.14	51.7	67.3	49.9	62.6	72.8	6.3	..
Corn+urea	6	4552	9.93	72.5	71.5	64.5	66.8	77.3	17.4	69
Sweet potato	9	4420	7.14	51.2	66.0	39.7	50.2	76.3	5.6	..
Sweet potato+urea	8	4419	9.93	72.8	67.2	52.6	51.2	77.9	16.0	77

[1] Supplied as DuPont "Two-Sixty-Two" feed compound.
[2] Calculated value. Thomas-Mitchell method (Maynard, 1951).

of the nitrogen added as urea to each ration. Differences between these two urea-containing rations in total nitrogen retention, expressed either in absolute amounts or as a percent of intake, were not significant. The nitrogen of the urea-supplemented sweet potato ration, however, had a significantly higher biological value than that of the corresponding corn ration. This calculated value, expressing the percentage utilization of absorbed nitrogen, was 77 for the sweet potato ration and 69 for the corn ration. Similarly calculated values for the sweet potato and corn rations before supplementation with urea were 85 and 77, respectively. It becomes evident, therefore, that differences between the supplemented rations in biological value of nitrogen can be related to differences in these values in the basal rations themselves. From this relationship it appears that urea nitrogen was as efficiently utilized in one ration as the other.

The results obtained in experiment 2 with rations of corn, barley and milo fed to six steer calves weighing about 500 lb. are given in table 3. To make the unsupplemented rations equal in protein, small amounts of soybean oil meal were included in the corn and milo rations. The nitrogen content of the unsupplemented and urea-supplemented rations, which was equivalent to 8.2 and 11.6 percent protein, respectively, was higher in this experiment than in experiment 1. The digestibility of dry matter in the unsupplemented rations varied only slightly from 63 percent. Protein digestibility was significantly lower in the milo ration than in the corn or barley rations (39.9 percent as compared to 47.2 and 51.2 percent), and crude fiber digestibility was lowest in the barley ration (60 percent).

Supplementation of each ration with 45 gm. of urea was without effect on the digestibility of nutrients other than protein. Protein digestibility increased, due largely to the greater nitrogen intake, from 47.2 to 61.6 percent in the corn ration, from 51.5 to 65.7 percent in the barley ration, and from 39.7 to 57.8 percent in the milo ration.

Supplementation of the barley ration with soybean meal, by partial replacement of grain to produce a ration similar in nitrogen content to the barley-urea ration, effected an increase in the average digestibility of all nutrients. Protein digestibility in the soybean meal-supplemented ration was 66.9 percent. Differences in nutrient digestibility between the soybean meal- and urea-supplemented barley rations, although small in all cases, were in favor of the soybean meal supplement.

TABLE 3. THE SUPPLEMENTAL VALUE FOR STEER CALVES OF UREA[1] ADDED TO CORN, BARLEY AND MILO RATIONS, AND A COMPARISON OF UREA WITH SOYBEAN OIL MEAL

Ration Identification	Number of Trials	Daily Feed Intake			Nutrient Digestibility				Nitrogen Retained Daily	Biological Value of Nitrogen[2]
		Dry Matter	Protein (N×6.25)	Nitrogen	Dry Matter	Protein	Crude Fiber	N-Free Extract		
		gm.	%	gm.	%	%	%	%	gm.	%
Corn	6	3366	8.29	44.4	64.3	47.2	65.7	68.7	6.9	..
Corn+urea	6	3414	11.65	63.3	64.6	61.6	66.2	68.3	11.6	64
Barley	6	3357	8.23	43.9	62.8	51.5	60.0	68.6	6.9	..
Barley+urea	6	3405	11.58	62.9	62.9	65.7	59.9	68.3	11.1	61
Barley+soybean meal	6	3383	11.60	63.7	67.6	66.9	63.6	72.5	12.8	63
Milo	6	3362	8.22	44.1	62.4	39.9	64.6	67.6	4.6	..
Milo+urea	6	3394	11.56	63.0	64.6	57.8	64.3	70.2	10.5	66

[1] Supplied as DuPont "Two-Sixty-Two" feed compound.
[2] Calculated value. Thomas-Mitchell method.

Steers retained only 4.6 gm. of nitrogen per day on the unsupplemented milo ration as compared to 6.9 gm. on the corresponding corn and barley rations. This difference, apparently related to a lower digestibility of protein in the milo ration, did not prove statistically significant. Supplementation of the rations with urea increased nitrogen retention by 4.7 gm. with the corn ration, 4.2 gm. with the barley ration, and 5.9 gm. with the milo ration. Thus, differences between the corn and milo rations became less after supplementation with urea. The increase in retention produced by the soybean meal supplement in the barley ration was 5.9 gm.

The calculated biological value of nitrogen in the supplemented rations ranged from 61 to 66. Differences in these values between the supplemented rations including the barley-soybean meal ration were not significant. Nevertheless, the trend of digestibility and nitrogen retention results strongly suggests that soybean meal is superior to urea as a nitrogen supplement in barley rations; also, that milo rations supplemented with urea approach the value of corn rations similarly supplemented. Certainly the need for supplemental nitrogen, which can be supplied by urea, is greater in milo rations than in those based on corn.

The results of experiment 3, which was a comparison of rations of corn, corn and molasses, and molasses, are presented in table 4. In the unsupplemented molasses rations, relatively large amounts of soybean meal were required to raise protein levels to that of the corresponding corn ration. Dry matter digestibility in the three unsupplemented rations varied only slightly from 69 percent. Protein digestibility, however, decreased in rations with increased molasses plus soybean meal in a significant manner from 55.5 percent in the corn ration to 50.9 and 48.1 percent in the corn: molasses, and molasses rations, respectively. Average crude fiber digestibility was lowest in the molasses ration (67.4 percent). Since there is no reason to believe that soybean meal itself is less digestible than corn, these results are in general agreement with those of Briggs and Heller (1940, 1943) who reported a depressing effect of molasses on digestibility of protein and crude fiber in lamb-fattening rations.

As in the previous experiment, urea was without effect on digestibility of ration nutrients other than protein. Digestibility of protein in the urea rations of corn and of increasing molasses content was 67.2, 65.6 and 62.9 percent, respectively.

Average nitrogen retention on the unsupplemented corn ration was

TABLE 4. THE SUPPLEMENTAL VALUE FOR STEER CALVES OF UREA [1] ADDED TO CORN AND MOLASSES RATIONS

Ration Identification	Number of Trials	Daily Feed Intake			Nutrient Digestibility				Nitrogen Retained Daily	Biological Value of Nitrogen [2]
		Dry Matter	Protein (N×6.25)	Nitrogen	Dry Matter	Protein	Crude Fiber	N-Free Extract		
		gm.	%	gm.	%	%	%	%	gm.	%
Corn	5	3338	8.50	45.2	69.3	55.5	69.5	73.8	12.2	..
Corn+urea	6	3388	11.84	64.2	68.1	67.2	69.6	70.4	17.9	70
Corn 50, molasses 50	6	3285	8.72	45.9	69.6	50.9	69.2	75.6	10.2	..
Corn 50, molasses 50+urea	6	3333	12.15	64.7	70.5	65.6	69.8	75.0	14.4	65
Molasses	6	3230	8.95	46.3	68.2	48.1	67.4	74.6	8.5	..
Molasses+urea	6	3264	12.44	64.9	68.3	62.9	67.2	73.4	13.3	65

[1] Supplied as DuPont "Two-Sixty-Two" feed compound.
[2] Calculated value. Thomas-Mitchell method.

relatively high (12.2 gm. daily), and decreased to 10.2 and 8.5 gm. as increased amounts of corn were replaced in the ration by molasses and soybean meal. Urea supplementation significantly increased nitrogen retention to 17.9 gm. in the corn ration, to 14.4 gm. in the corn: molasses ration and to 13.3 gm. in the molasses ration. A comparison of these values for corresponding rations reveals that the same amount of supplemental urea effected a greater increase in nitrogen retention with the corn ration (5.7 gm.); than with the corn-molasses ration (4.2 gm.); or the molasses ration (4.8 gm.). It is evident that full advantage was not taken of the potential value of urea as a nitrogen supplement in the molasses rations. Apparently a considerable proportion of the urea nitrogen in the latter rations was absorbed and excreted without contributing to nitrogen retention. The biological value of nitrogen, which was significantly higher in the corn-urea ration than in the molasses-urea rations (70 as compared to 65) provided additional evidence of the less efficient utilization of urea nitrogen in the molasses rations. Biological values calculated for the nitrogen of the unsupplemented rations averaged 86; differences between the individual values were not statistically significant.

Summary

The value of urea as a source of nitrogen in rations containing different carbohydrate feeds was determined in three series of digestion and nitrogen balance trials with Hereford steers. The carbohydrate feeds used in formulating the different rations were yellow corn, dehydrated sweet potatoes, milo, barley, cane molasses and combinations of cane molasses and corn. Each of these feeds was combined with prairie hay and sufficient protein supplement to provide basal rations having 7–8 percent crude protein. Urea in the form of "Two-Sixty-Two" was added to each ration in amounts required to provide a total of 11–12 percent protein equivalent.

There were some differences among the basal rations in digestibility of nutrients ascribed to differences in the carbohydrate feeds. Addition of urea had very little effect on apparent digestibility of nutrients, other than protein ($N \times 6.25$) which was increased in all rations. It improved nitrogen retention to a significant extent when added to each ration, a greater improvement being made when it was added to the corn ration than when added to the molasses rations.

Biological values calculated for the total nitrogen of the supple-

mented rations indicated that the urea nitrogen was utilized with equal efficiency in rations of different cereal grains and sweet potatoes, and with less efficiency in molasses-containing rations.

In a comparison of urea with soybean meal in barley rations, small differences in nutrient digestibility and nitrogen retention favored the soybean meal supplement.

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THE VALUE OF SEVERAL AMMONIATED PRODUCTS AS FEED FOR BEEF CATTLE

RALPH MCCALL and W. R. GRAHAM, JR.

The Quaker Oats Company

A GROWING shortage of high protein feeds has developed in recent years. This is due to larger livestock and poultry numbers plus more general use of protein supplements, particularly in high roughage rations. Millar (1941, 1942, 1944) showed that many substances may be ammoniated to form stable protein substitutes for ruminant animals. Culbertson *et al.* (1950), Knodt *et al.* (1950, 1951), Magruder *et al.* (1951) and Tillman *et al.* (1951) reported successful feeding of ammoniated molasses and fermentation by-products to growing cattle, fattening steers, and milking cows. These experiments confirm the value of ammoniated products in ruminant feeding.

Materials and Methods

Ammoniated cane molasses, ammoniated citrus pulp and a by-product from the production of furfural were fed in this study. The latter product is composed of hydrolyzed and ammoniated corn cobs and oat hulls, and is referred to in this report under the brand name of Furameal. The protein equivalent values ($N \times 6.25$) of the ammoniated products were approximately 24 percent for cane molasses and citrus pulp, and 35 percent for Furameal.

Four experiments were conducted in which the above materials were compared as protein supplements for fattening steers. The control supplement in each experiment contained no ammoniated ingredient. Uniform groups of Hereford steers were used in each experiment. Initial and final weights were the average of two or three weights. Twice-a-day hand feeding was practiced. Individual 28-day weights were taken. Ground ear corn was fed the first part of the fattening period, but all or part of the ear corn was gradually replaced by cracked shelled corn during the third to the fifth 28-day period. The corn was fed *ad libitum* in order to evaluate more clearly the effects of these supplements on appetite, a major factor in feedlot performance.

The first experiment was a comparison of a 32 percent protein

supplement containing 3 percent urea as a source of approximately ¼ of the protein, and a 32 percent protein control supplement. Each supplement was fortified with 9 percent cane molasses, 3 percent dicalcium phosphate and 1 percent of iodized salt plus the trace minerals, cobalt sulphate, copper sulphate, iron sulphate, and manganese sulphate and D-Activated animal sterol. The supplements were fed at the rate of 10 percent of the concentrate mixture. A high molasses feed (containing 40 percent molasses, ground grain screenings, cottonseed meal and soybean meal to produce 12 percent protein), corn, and fair quality first cutting alfalfa hay were also fed.

In the second experiment, 20 percent of ammoniated molasses and 20 percent of ammoniated citrus pulp were used to replace approximately 1/6 of the protein in a 32 percent protein supplement, and were compared to a 32 percent protein control supplement. In a fourth supplement, ammoniated molasses was included at the 10 percent level, and supplied about 1/12 of the protein equivalent. This supplement also contained zinc sulphate, potassium sulphate, calcium sulphate, sodium bicarbonate, and corn distillers' solubles, in addition to mineral fortification similar to that of the supplements fed in the first experiment. The control supplement also contained 12 percent of dehydrated alfalfa meal and dehydrated grass meal. The first cutting alfalfa hay fed in this test was poor in quality and the corn high in moisture. The data on corn consumption presented in table 2 are corrected to 16 percent moisture for ground ear corn and 15 percent moisture for the shelled corn.

In the third experiment, 2 percent of urea, 20 percent of ammoniated molasses and 11.5 percent of Furameal replaced approximately ⅕ of the protein, respectively, in supplements with 24 percent protein equivalent. A 24 percent protein control supplement was also fed. All supplements were fortified with 5 percent of dehydrated alfalfa meal and dehydrated grass meal, 2½ percent steamed bone meal, and 1½ percent calcium carbonate, plus iodized salt, trace minerals and D-Activated animal sterol as in the previous experiments. The control supplement and the supplement having urea contained 17 percent of cane molasses. The first cutting alfalfa hay fed was only fair in quality and the corn about average quality.

The fourth experiment was a comparison of 2 levels—⅕ and ⅖—of supplementary protein replacement by Furameal, ⅕ supplementary protein replacement each by Furameal and ammoniated molasses, and a 24 percent protein control supplement, for fattening steers. The

fortification of these supplements was similar to that in the third experiment. The first cutting alfalfa hay fed was fair to poor in quality, and the corn about average in quality.

TABLE 1. THE COMPARATIVE VALUE OF UREA AND PROTEIN IN THE SUPPLEMENT FOR FATTENING STEERS

(146 Days—810 Lb. Short Two-Year Old Steers)

Group	1	2
Supplement	32% Protein Control	¼ Protein from Urea
No. of steers	14	14
Av. gain per steer (lbs.)	439.4	423.0
Av. daily gain (lbs.)	3.01	2.90
Av. daily feed (lbs.)		
Supplement	2.12	2.10
Molasses feed	2.12	2.10
Ground ear corn	6.90	6.86
Shelled corn	10.10	9.97
Hay	6.47	6.56
Feed per cwt. gain (lbs.)		
Supplement	71	73
Molasses feed	71	73
Ground ear corn	229	237
Shelled corn	335	344
Hay	215	226
Carcass grades		
High choice	8	12
Low choice	6	2
Dressing percent	61.94	61.73

Results

First Experiment

The steers in the control group 1 (table 1) made a daily gain of 3.01 pounds during the 146 day feeding period. The urea-fed steers in lot 2 made 0.11 pounds per day less gain. This difference in gain was not statistically significant. The urea-fed steers required about 3 percent more concentrate and 5 percent more roughage than the control group to produce 100 pounds of gain. The feces of these steers were considerably more loose than normal during the latter part of the fattening period. The urea-fed steers had a slightly higher average carcass grade but a slightly lower dressing percentage than the controls.

Second Experiment

The average daily gains of the four groups of steers were very similar, ranging from 2.35 pounds to 2.40 pounds as reported in table 2. There was also very little difference between groups in the feed required to produce 100 pounds gain. The supplement fed to group 3 con-

TABLE 2. THE COMPARATIVE VALUE OF AMMONIATED MOLASSES, AMMONIATED CITRUS PULP, AND PROTEIN IN THE SUPPLEMENT FOR FATTENING STEERS

(170 Days—748 Lb. Yearling Steers)

Group	1	2	3	4
Supplement	32% Protein Control	1/6 Protein from Ammon. Molasses	1/12 Protein from Ammon. Mol.; Added Min. and Vit.	1/6 Protein from Ammon. Citrus Pulp
No. of steers	16	16	16	16
Av. gain per steer (lbs.)	407.6	408.3	400.2	405.1
Av. daily gain (lbs.)	2.40	2.40	2.35	2.38
Av. daily feed (lbs.)				
Supplement	1.68	1.68	1.68	1.68
Molasses feed	1.49	1.49	1.49	1.49
Ground ear corn	10.33	10.30	10.38	10.22
Shelled corn	6.50	6.77	6.64	6.58
Corn silage	5.30	5.43	5.24	5.14
Hay	2.19	2.15	2.16	2.19
Feed per cwt. gain (lbs.)				
Supplement	70	70	72	71
Molasses feed	62	62	63	62
Ground ear corn	431	429	441	429
Shelled corn	271	282	282	276
Corn silage	221	226	223	216
Hay	91	89	92	92
Carcass grades				
U. S. prime	9	12	12	9
U. S. choice	7	4	4	7
Dressing percent	61.86	62.68	62.03	62.04

taining added minerals, corn distillers' solubles, and ammoniated molasses as a replacement of 1/12 of the supplementary protein, produced no improvement in amount of gain or in efficiency of gain compared to that of the control group. The ammoniated molasses fed steers had the highest average carcass grade, and all groups getting ammoniated products had a higher dressing percentage than the control group.

The supplements containing ammoniated molasses and ammoniated citrus pulp were fully as palatable as the control supplement. The

steers fed these ammoniated supplements were as free from digestive disturbances as those fed the control supplement.

Third Experiment

The average daily gains for the steers getting the 24 percent protein control supplement and the supplement containing Furameal

TABLE 3. THE COMPARATIVE VALUE OF UREA, FURAMEAL, AMMONIATED MOLASSES, AND PROTEIN IN THE SUPPLEMENT FOR FATTENING STEERS

(168 Days—812 Lb. Short Two-Year Old Steers)

Group	1	2	3	4
Supplement	24% Protein Control	1/5 Protein from Urea	1/5 Protein from Ammon. Molasses	1/5 Protein from Furameal
No. of steers	13	13	12	13
Av. gain per steer (lbs.)	444.6	429.1	422.2	442.4
Av. daily gain (lbs.)	2.65	2.55	2.51	2.63
Av. daily feed (lbs.)				
Supplement	3.01	3.02	3.00	3.03
Ground ear corn	12.20	12.11	12.12	12.65
Shelled corn	7.39	7.59	7.20	7.94
Hay	4.16	4.22	4.36	4.29
Feed per cwt. gain (lbs.)				
Supplement	114	118	119	115
Ground ear corn	461	474	482	480
Shelled corn	279	297	286	302
Hay	157	165	173	163
Carcass grades				
U. S. prime	5	5	7	6
U. S. choice	8	8	5	7
Dressing percent	61.99	62.37	62.27	62.19

were almost identical--2.65 pounds and 2.63 pounds respectively (table 3). The steers fed the supplement containing urea (group 2) made an average daily gain of 2.55 pounds. Those getting the supplement containing ammoniated molasses (group 3) made an average daily gain of 2.51 pounds. The ammoniated molasses fed steers made the fastest gains through the third 28-day period, averaging 3.11 pounds at that point. Feed consumption and gains by these steers averaged lower during the remainder of the experiment than for the steers in the other 3 groups. Possibly this group had been given a little too much feed at one point which took the edge off their

appetite for a while. There was practically no difference in the feed required to produce 100 pounds gain for the steers fed urea, ammoniated molasses, and Furameal. The control group required from 4 percent to 5 percent less concentrate, and 4 percent to 10 percent less roughage to produce 100 pounds gain than those getting the above sources of non-protein nitrogen.

TABLE 4. THE COMPARATIVE VALUE OF DIFFERENT LEVELS OF FURAMEAL, AMMONIATED MOLASSES, AND PROTEIN IN THE SUPPLEMENT FOR FATTENING STEERS

(166 Days—775 Lb. Yearling Steers)

Group	1	2	3	4
Supplement	24% Protein Control	1/5 Protein from Furameal	2/5 Protein from Furameal	1/5 Protein from Ammon. Mol.; 1/5 Protein from Furameal
No. of steers	16	16	16	16
Av. gain per steer (lbs.)	422.4	425.6	428.4	436.7
Av. daily gain (lbs.)	2.54	2.56	2.58	2.63
Av. daily feed (lbs.)				
Supplement	3.00	3.00	3.00	3.00
Ground ear corn	17.13	17.41	18.23	17.71
Shelled corn	2.09	2.19	2.28	2.24
Hay	3.52	3.70	3.85	3.84
Feed per cwt. gain (lbs.)				
Supplement	118	117	116	114
Ground ear corn	673	679	706	673
Shelled corn	82	85	88	85
Hay	138	144	149	146
Carcass grades				
U. S. prime	8	7	4	11
U. S. choice	8	9	12	5
Dressing percent	61.38	61.02	61.08	61.85

The average carcass grades and dressing percentages for the 4 groups were quite similar. The steers getting the supplements containing ammoniated molasses and Furameal had the highest average carcass grade, but those getting the supplement containing urea averaged slightly highest in dressing percentage.

Fourth Experiment

Table 4 shows that the steers fed supplements containing Furameal and ammoniated molasses gained slightly more than those fed the

control supplement containing 24 percent protein. The higher level of Furameal produced slightly more daily gain than the lower level.

The steers fed Furameal as a partial replacement of supplementary protein in all groups in this and the previous experiment, ate more corn (fed *ad libitum*) than the control group. This appetite stimulation could have considerable practical value. Practically no digestive disturbances were experienced with any of these steers.

There were very small differences in the feed required to produce 100 pounds gain by the steers in all groups with the exception of those in group 3 fed the higher level of Furameal. The steers in this group required about 5 percent more feed than the control group to produce 100 pounds gain.

The steers fed a combination of ammoniated molasses and Furameal had a definite advantage in carcass grade, as 11 out of 16 carcasses in this group graded prime compared to 8 out of 16 prime carcasses in the control group. These steers also excelled in dressing percentage, averaging 61.85 percent compared to 61.38 percent for the controls. Fewer steers graded prime in group 3 fed the high level of Furameal than in the other groups. However, 9 of the choice steers in this group graded high choice, and there was little difference in the average carcass grade of this group and the control group.

Summary

1. Furameal (35 percent protein equivalent and composed of hydrolyzed and ammoniated corn cobs and oat hulls) was as effective as protein in producing gain when fed to fattening steers as a replacement of 1/5 to 2/5 of the supplemental protein. Steers fed the low level of Furameal had about the same feed conversion as those fed the control supplement, but those fed the higher level of Furameal had slightly lower feed efficiency than that of the control group. There was little difference between groups in average carcass grade or in dressing percentage.

2. Ammoniated molasses (24 percent protein equivalent) was as effective as protein in one test, but slightly less effective in a second test, when fed to fattening steers as a replacement of 1/5 or less of the supplemental protein. There was little difference in feed efficencies of these groups, but steers getting the ammoniated supplement had higher average carcass grade in both tests and a higher dressing percentage in one test.

3. A combination of Furameal and ammoniated molasses was slightly

more effective than protein in producing gain when fed to fattening steers as a replacement of ⅖ of the supplemental protein. Steers fed the ammoniated supplement had as good feed conversion as the controls, but higher average carcass grade and dressing percentage.

4. Urea was slightly less effective than protein when fed to fattening steers in 2 tests as a replacement of ⅕ and ¼ of the supplemental protein. Steers fed the supplement containing urea had slightly lower feed conversion than the controls. There was little difference between the two groups in average carcass grade and dressing percentage.

5. These studies indicate that the non-protein nitrogen materials tested were satisfactory protein substitutes for fattening steers when fed to the level of 40 percent of the protein supplement.

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THE VALUE OF CERTAIN SUPPLEMENTS FOR BEEF CATTLE FED HARVESTED GREEN ALFALFA

J. H. Meyer, G. P. Lofgreen and F. K. Hart

University of California [1]

THE feeding of green forage, usually defined as soilage, to animals has not generally been considered economically feasible until recently. Soilage feeding in certain areas of California has become an established practice and may prove under some conditions to have certain economical advantages over the feeding of hay or pasturing. An opportunity exists for valuable experimental studies with soilage because, in this case, the weight of the green forage can be determined by simple weighing and sampling techniques which are not possible in pasture studies.

The studies reported in this paper were designed to investigate the supplemental value of dry hay, barley, and molasses when fed in combination with chopped green forage.

Experimental

This study was made during July and August, 1952, with irrigated alfalfa in the desert regions of Southern California. Four fields of alfalfa were used for the experiment. The alfalfa was first harvested in a field when it reached a stage just before bloom and continued until the full bloom stage had been reached, at which time the remaining forage was harvested as hay. It was necessary to use a portion of a fifth field at the end of the second thirty-day period. Two cuttings were used; one during each thirty-day period. Records were kept on acreages used.

One hundred and sixty Brahman crossbred steers and heifers were divided into two lots of 80 animals each and 106 heavier animals were assigned to a third group. They were fed in feed-lots with ample shade provided by trees. The average morning and evening temperature at feeding was 75° F. and 101° F. respectively with peak daytime temperatures as high as 117° F. The cattle were weighed in groups of five at 30-day intervals after an overnight stand without feed or water.

[1] Department of Animal Husbandry, Davis, California.

The Department of Animal Husbandry is pleased to acknowledge the cooperation of Mr. Dana Fisher of Blythe, California, upon whose ranch these experiments were conducted.

Three feedings per day were used for the first 30 days until it was noted that very little feed was consumed at the noon feeding due to the midday heat. It was then eliminated. Alfalfa was harvested green by a field forage chopper and blown directly into a self-unloading wagon. The previously weighed wagon and forage were then taken to a truck scales and weighed. At this time samples of the forage were taken for dry matter analysis. Weighed amounts of supplements were put through a hammer-mill and blown on top of the forage. Forage and supplements were mixed quite well as the wagon unloaded the feed at the feedlots. Feed refusals were weighed back and sampled. It was necessary to feed alfalfa hay once or twice during each period when rain made forage harvesting impossible.

Representative aliquots were taken of the green alfalfa during the trial. These were dried and brought to Davis for a digestion trial. Total digestible nutrients were determined in the manner suggested by Lofgreen (1953) using wethers as the experimental animals.

The experimental design for the first 30-day period included a control lot (lot 1) of 80 animals on green alfalfa alone plus a minimum amount of Sudan hay to control scours and bloat. Lot 2 received the above ration plus free access to Sudan hay placed in a second feed bunk area. This was done because of previous observations that cattle on green feed seemed to desire additional dry feed. Lot 3 received the same ration as lot 1 plus one pound of barley per 100 pounds of body weight.

Results of the first 30-day period prompted a change in the design for the second 30 days. Lot 1, the control lot, was continued on the same ration. The observation that low gains might be due to low feed consumption prompted spraying molasses on the green feed of lot 2. As the animals in lot 3 were near market condition, they were marketed and discontinued from the experiment.

Results and Discussion

The results of the first 30-day period, presented in table 1, give information on gains and feed consumption. The average daily gain of the animals on green alfalfa alone plus a minimum of Sudan hay (lot 1) was 1.10 pounds. Even though the cattle in lot 2 did eat a large amount of Sudan hay, there was no improvement in daily gain when compared to lot 1. The addition of barley to the ration of lot 3 increased the daily gain to 1.65 pounds.

The controls, lot 1, consumed about 55 pounds of green alfalfa

which was equivalent to 13.3 pounds of alfalfa hay. This, plus 4.2 pounds of Sudan hay and 0.8 pounds of alfalfa hay, equaled 18.3 pounds of air-dry feed per head per day. A relatively good feed efficiency of roughage utilization was obtained in the 1482 pounds of feed consumed per 100 pounds gain. The animals in lot 2 consumed approximately equal amounts of green alfalfa and Sudan hay (air-dry basis). This increased the amount of feed required per 100 pounds of gain. As would be expected, the barley in the ration of lot 3

TABLE 1. RESULTS OF FIRST THIRTY-DAY PERIOD

Category of Interest	Lot 1 Green Alfalfa	Lot 2 Green Alfalfa Sudan Hay, Free-Choice	Lot 3 Green Alfalfa Barley
No. of animals	80	80	106
Initial weight, lbs.	630	650	764
Average daily gain, lbs.	1.10	1.19	1.65
Feed per head per day, lbs.:			
Alfalfa, wet basis	55.3	44.8	40.4
Sudan hay	4.2	10.6	4.7
Barley	...	...	7.9
Alfalfa hay	0.8	0.2	0.9
Total, air-dry basis	18.3	21.6	23.2
Feed refused, air-dry basis	2.0	1.4	1.8
Feed consumed per 100 lbs. gain	1482	1697	1297

increased the efficiency of feed utilization as reflected in the pounds of feed consumed per 100 pounds of gain.

The gains made by the animals in the control lot are just about what should be expected from the feed consumption. It appeared, therefore, that an increase in feed consumption might be desirable. The design for the second 30-day period was therefore altered to include spraying of molasses on the green feed of lot 2. Lot 1 was left on the same regime. The response of lot 1 was almost identical to period 1 as shown in table 2. The use of molasses to increase feed consumption gave some unexpected results. While consumption of green alfalfa by lot 2 increased, the gains and feed efficiency decreased. For some reason, unknown at this time, the addition of molasses to green alfalfa was not compatible for maximum utilization of feed.

Table 3 indicates the total production of dry matter and beef.

TABLE 2. RESULTS OF SECOND THIRTY-DAY PERIOD

Category of Interest	Lot 1 Green Alfalfa	Lot 2 Green Alfalfa Sudan Hay, Free-Choice Molasses
No. of animals	80	80
Initial weight, lbs.	664	684
Average daily gain, lbs.	1.24	0.94
Feed per head per day, lbs.		
Alfalfa, wet basis	59.5	53.9
Sudan hay	2.9	5.6
Molasses	...	1.7
Alfalfa hay	0.8	0.9
Total, air-dry basis	20.4	23.4
Feed refused, air-dry basis	2.0	1.8
Feed consumed per 100 lbs. gain	1484	2298

Since the feed for all lots was harvested from the same field on the same day, dry matter production per acre was the same for all lots. There was a 45 percent decrease in forage production the second period. The total gain of the lots was apportioned into the gain due to green alfalfa and gain due to supplements. This was done by assuming TDN values from Morrison (1948) for all feed except the green alfalfa for which TDN was determined. Then arbitrarily a part of the total gain was assigned to each on basis of the proportion of TDN furnished. On this basis lot 1 (green alfalfa) and lot 3

TABLE 3. SUMMARY OF PRODUCTION

	1st Period			2nd Period	
Category of Interest	Lot 1 Green Alfalfa	Lot 2 Green Alfalfa Sudan Hay	Lot 3 Green Alfalfa Barley	Lot 1 Green Alfalfa	Lot 2 Green Alfalfa Sudan Hay Molasses
Total green alfalfa fed, oven-dry, lbs.	29,658	22,432	28,704	34,901	33,883
Total acres	10.3	7.8	9.9	22.2	21.5
Total gain, lbs.	2740	2755	5410	2878	2325
Gain due to green alfalfa, lbs.[1]	1989	1309	1894	2294	1469
Gain produced per acre from green alfalfa, lbs.	193	168	191	103	68

[1] Total gain times proportion of TDN furnished by green alfalfa.

(green alfalfa plus barley) produced the same amount of beef per acre in the first period. A 12.5 percent drop in beef production per acre from green alfalfa was noted for the animals receiving Sudan hay free choice. An even greater drop in beef production occurred during the second period when molasses was sprayed on the green forage. Thirty-four percent less beef was produced per acre in this lot than by the controls.

Table 4 presents a comparison of calculations of the TDN of the ration by two methods—namely, by maintenance and body gain

TABLE 4. TOTAL DIGESTIBLE NUTRIENTS

	1st Period			2nd Period	
Category of Interest	Lot 1 Green Alfalfa	Lot 2 Green Alfalfa Sudan Hay	Lot 3 Green Alfalfa Barley	Lot 1 Green Alfalfa	Lot 2 Green Alfalfa Sudan Hay Molasses
Total TDN required for maintenance	11,784	12,072	18,094	12,312	12,480
Total TDN required for gain	9672	9725	19,097	10,159	8207
Total TDN required	21,456	21,797	37,191	22,471	20,687
Total dry matter consumed	36,095	41,698	61,815	39,323	47,493
Calculated TDN, dry matter:					
From requirements	59.4	52.3	60.2	57.1	43.5
From digestion trial [1]	54.8	55.2	65.9	54.7	55.9

[1] Calculated from digestion trial on green alfalfa and using Morrison's (1948) figures for the other feeds.

requirements and by use of digestion trial data on a composite of samples of the green alfalfa. The method used to calculate maintenance requirements was that of Brody *et al.* (1934) and that used to calculate TDN required for gain is that suggested by Knott *et al.* (1934). The total digestible nutrients of the green alfalfa was 54.4 percent on the oven-dry basis as determined by the digestion trial. Morrison's (1948) TDN figures were used for the other feeds.

It can be noted in table 4 that the TDN of ration of lot 1, period 1, as determined from requirements was approximately equal to the barley ration and higher than the Sudan hay free-choice ration. The total TDN of the ration calculated from the TDN values given by Morrison (1948) for barley, molasses, Sudan hay, and from the TDN

determined in green alfalfa, did not give the same picture. The TDN of the rations of lots 1 and 2 were approximately equal but lower than that of the ration of lot 3. In other words, the gains of lot 1 (green alfalfa alone) were greater than expected from the TDN of the ration calculated from literature values and digestion trial data while the gains of lot 2 (plus Sudan hay free-choice) and lot 3 (plus barley) were less than one would expect. This might indicate an excellent utilization of the ration containing the largest proportion of green alfalfa and a decrease in its utilization when either Sudan hay or barley were added.

During the second period, the same trend was indicated for lot 1 as far as the TDN results from the two methods were concerned. The difference between the TDN calculated by the two methods was 12.4 percent for lot 2. As noted before, this indicates a poorer utilization of the ration with the addition of molasses.

Summary

Data are reported from an experiment with beef cattle on the value of Sudan hay, barley, and molasses as supplements for cattle fed alfalfa soilage. The cattle fed green alfalfa plus a minimum of Sudan hay to prevent bloat and scours gained an average of 1.17 pounds per day and produced 193 and 103 pounds of beef per acre for the two successive 30-day periods respectively. Sudan hay free-choice caused little change in daily gain but a slight decrease in production of beef. Barley increased daily gains but did not increase beef production per acre. Molasses not only decreased gains but lowered substantially the amount of beef produced. Calculations of TDN by two methods are compared and discussed.

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ANTIBIOTICS AND THE REPRODUCTION OF SWINE[1]

L. E. CARPENTER and NORA LARSON
Hormel Institute[2]

THE discovery that antibiotics increased the growth rate of swine (Jukes *et al.*, 1950, and Carpenter, 1950), stimulated much interest in the use of antibiotics in the diets of swine. In a short-time feeding experiment, the effect of feeding the antibiotic, aureomycin, during the last 49 to 90 days of the gestation period and throughout a 56 day lactation period was observed to have no harmful or beneficial effect on the reproduction performance of swine (Carpenter, 1951). Since antibiotics are now being widely used in swine diets, it is desirable to know the effect of feeding antibiotics over a long period on reproduction.

Workers at the University of Notre Dame (Luckey, 1952) observed that antibiotics had no growth stimulating properties when fed to germ-free chicks, indicating that the growth stimulating properties are due to an indirect effect on the animal. Jukes (1952) observed that aureomycin injected into the chick embryo, under sterile conditions, failed to stimulate growth. Since the embryonic pig receives its nourishment in a sterile environment, it would seem unlikely that antibiotics would influence the growth rate of the unborn pig even though they were transferred through the placental tissues.

In order to investigate further the effect of feeding antibiotics on reproduction in swine, three experiments have been conducted: (1) swine have been fed antibiotics from weaning through two complete gestation and lactation periods; (2) an attempt has been made to determine if dietary antibiotics entered the blood stream of the embryonic pig; and (3) the amount of aureomycin elaborated in the milk of sows fed aureomycin has been determined.

Procedures

Effect of Feeding Antibiotics Over a Long Period

The basal diet employed had the following composition: ground yellow corn, 41 percent; ground oats, 20 percent; alfalfa meal (dehydrated), 10 percent; soybean oil meal, 7 percent; tankage (60 percent

[1] Supported by the Hormel Foundation, Austin, Minn., and Lederle Laboratories, Pearl River, N. Y.
Hormel Institute No. 91.
[2] Austin, Minn.

protein), 10 percent; wheat middlings, 10 percent; commercial mineral, 2 percent; irradiated yeast (9000 USP units vitamin D per gram), 0.0125 percent. One group of gilts was fed the basal diet and another group received the same diet plus two grams of aureomycin per 100 lb. of feed as a vitamin B_{12} and antibiotic feeding supplement.[3] When the gilts weighed 180 to 200 lb., the level of dietary protein was reduced and the antibiotic level was reduced to one gram of aureomycin per 100 lb. of diet.

All animals were confined on concrete floors during the growing period and were then moved to drylots for the remainder of the experiment. During the lactation period they were confined in either 6′ x 7′ or 6′ x 15′ pens with concrete floors. All animals received the same management treatment.

The dams which received the aureomycin in the diet prior to parturition received one gram of antibiotic per 100 lb. of feed during the lactation period. All suckling pigs had access to the same creep diet which consisted of rolled oats with 1.8 gm. of aureomycin as a vitamin B_{12} and antibiotic feeding supplement per 100 lb. of feed. After the first 56 day lactation period, some of the dams in each group were selected to remain on their respective dietary regimes for a second gestation and lactation period.

Placental Transfer of Antibiotics

The placental transfer of antibiotics was studied by feeding or injecting either pure aureomycin hydrochloride or penicillin sodium G to sows shortly before parturition. Some sows were allowed to farrow and the pigs were bled from the jugular vein before they suckled their dams. In a few cases, the pigs were removed from the dams by hysterectomy. All pigs were bled within the first few hours after birth. All sows were bled either by marginal ear vein or uterine artery as soon as possible after the pigs were born.

Aureomycin was determined in the blood serums by the method of Dornbush and Pelcak (1948). Penicillin was determined in blood serum by the turbidimetric method (Foster *et al.*, 1951), using *micrococcus pyogenes* (variety aureus) 209P as the test organism.

Aureomycin in Sows' Milk

Lactating sows were fed aureomycin either as a vitamin B_{12} antibiotic feeding supplement or as pure aureomycin hydrochloride. The

[3] Contained 1.5 mg. Vitamin B_{12} and 1.8 gm. of aureomycin per pound, made available through the courtesy of Lederle Laboratories, Pearl River, New York.

sows were milked during a normal "let-down" period or during a "let-down" induced by an intravenous injection of posterior pituitary extract. The presence of aureomycin in the milk was determined by either the turbidimetric (McCulloch *et al.*, 1949) or by a methylene blue method (Schipper *et al.*, 1951).

Results and Discussion

Effect of Feeding Antibiotics Over a Long Period

The reproduction records of dams fed the antibiotic aureomycin from weaning through two complete gestation and lactation periods are given in table 1. The first litters farrowed by the dams fed the

TABLE 1. THE EFFECT OF AUREOMYCIN ON REPRODUCTION

Diet	Number of Sows	Number of Litters	Average per litter: Number Born Alive	Number Born Dead	Birth Weight (lb.)	Number Weaned	Weaning Weight (lb.)
			First Litters				
Control	16[2]	15	6.5	0.5	2.95	4.2	25.0
Aureomycin[1]	23[3]	17	7.9	0.4	2.98	5.6	27
			Second Litters				
Control	14	14	8.6	2.0	2.9	5.3	25.5
Aureomycin[1]	14	14	8.1	0.5	3.1	6.5	29.7

[1] 2 gm. aureomycin per 100 lb. of diet during the growing period and 1 gm. per 100 lb. thereafter.
[2] One sow did not exhibit heat.
[3] Two sows bred three times and one bred twice but did not conceive; two sows did not exhibit heat, and one became crippled and was removed.

antibiotic were larger than those farrowed by the control dams, but there was no significant differences in the birth weight of the pigs or in the number of pigs born dead. The record of performance for the second gestation and lactation period indicated that the control dams farrowed slightly larger litters with more dead pigs than did the dams fed the antibiotic. The dams fed the diet containing the antibiotic weaned more and heavier pigs per litter than did the control dams, but the differences were not significant.

One gilt in the control group and two in the antibiotic fed group did not exhibit oestrus. Three animals in the antibiotic fed group failed to conceive after two or three services while all the animals in the control group conceived. In this respect, the control gilts performed better than the average for the Hormel Foundation herd,

from which these animals were selected, while the antibiotic-fed group responded normally.

Placental Transfer of Antibiotics

Five sows were fed one gram of aureomycin hydrochloride in capsules three times a day prior to parturition. Feeding was started two days before the expected parturition date. In four cases the dams

TABLE 2. THE PLACENTAL TRANSFER OF ANTIBIOTICS IN SWINE

Sow No.	No. Pigs Bled	Amount Adm.	Time Elapsed from Final Adm. to Bleeding	Antibiotic in Serum	
				Sow	Pig [1]
			hr.	ug./ml.	
		Aureomycin Hydrochloride			
		gm.			
1	4	5	7	0.032	none
2	8	6	1	1.0	none
3	6	19	11	1.3	none
4	4	19	11	0.125	none
5	4	16	8	0.125	none
		Penicillin Sodium G		units/ml.	
		units			
6	4	900,000	34	0.125	none
7	4	900,000	79	none	none
8	4	1,000,000	18	0.256	none
9	5	1,000,000	3	0.5	none
10	2	1,000,000	2	4.0	none

[1] Serum from each pig assayed individually.

were allowed to farrow and in the other the pigs were removed by hysterectomy. A summary of the data is given in table 2. In no case was aureomycin detected in the serum of the newly born pigs although it was detected in the serum from all five sows. The values obtained by two different methods were not entirely consistent.

Other experiments not reported indicated that the addition of small amounts of aureomycin to blood or serum from pigs that never received the antibiotic could not be detected by the methods employed. No extraction procedure or other technics were found that aided in the recovery of small amounts of aureomycin. Large amounts could be detected readily with reasonable accuracy. Consequently, although

aureomycin was not detectable in the blood of pigs farrowed by dams that received the antibiotic it may have been present in small amounts, bound, or in some inactive form.

Tests with penicillin demonstrated that when this antibiotic was added to blood it could be recovered, even at very low concentrations. Therefore tests were conducted on sows near term to investigate the placental transfer of penicillin. Penicillin sodium G was injected intramuscularly in the neck region of the sow just prior to parturition and the pigs were taken from the sow in four cases by hysterectomy and in one case the sow was allowed to farrow. The results given in table 2 demonstrate that although antibiotic activity was detected

TABLE 3. AUREOMYCIN IN THE MILK AND BLOOD SERUM OF SOWS

Number of Sows	Amount of aureomycin administered to sows		Aureomycin content of milk and serum							
			—0 days		2 days		4 days		6 days	
	in diet[1]	by capsule	M[2]	S[3]	M	S	M	S	M	S
	gm.		Micrograms per ml.							
2	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0.06	0.03	0	0	0.25	0
1	0	5	0	0	0.06	0.7	+[4]	0	0.5	+
1	1	5	0	0	+	0	+	0.25	0	0

[1] gm. per 100 lb. of feed continuously.
[2] Milk.
[3] Serum.
[4] Trace.

in the serum of all five sows none was detected in the serum of the pigs, indicating that penicillin did not enter the embryonic blood system.

Secretion of Aureomycin in the Milk of Sows

Lactating sows given aureomycin in the diet or by capsule were milked at various intervals and the amount of aureomycin in the milk determined. Serum from samples of blood collected at the time of milking were also assayed for aureomycin. The data in table 3 indicate that sows fed aureomycin at a level of 1 gm. per 100 lb. of feed do not consistently elaborate milk that contains aureomycin in detectable amounts. When sows were given large amounts of aureomycin orally by capsule the milk contained detectable levels of aureomycin for several days but the amount varied considerably.

Discussion

The results presented here on feeding aureomycin to sows over a long period confirm the previous results that the antibiotic does not have a harmful or beneficial effect on reproduction. The sows in this experiment were fed rather high levels of antibiotic over a period of about one and a half years without harmful effects; therefore, it is reasonable to assume that feeding lower levels (5 or 10 gm. per ton) would not have an adverse effect on reproduction.

The evidence presented here strongly indicates that neither of the two antibiotics tested is transferred through the placenta to the embryonic circulation. Since the unborn pig is growing in a sterile environment it would seem very unlikely that antibiotics would exert a favorable influence on growth even though they did transfer across the placenta.

It would seem, therefore, that antibiotic feeding during gestation could only be expected to have an indirect favorable influence on reproduction by controlling such factors as "disease level" in the dam or by a "sparing" action when fed with diets of marginal nutritional value.

The amount of aureomycin secreted in the milk of sows fed 1 gm. of aureomycin per 100 lb. of feed was very low, too small to influence growth rate of suckling pigs. The increase in growth rate of suckling pigs observed during the lactation period in the experiments reported herein was not apparent until after the third week or after the pigs started to consume solid feed. The pigs suckling antibiotic-fed dams had access to her diet as well as the creep diet and very likely consumed more antibiotic than those nursing the control dams.

Summary

Feeding the antibiotic aureomycin to swine from weaning through two gestation and lactation periods did not have a harmful or beneficial effect on reproduction.

Neither aureomycin nor penicillin was observed to be transferred across the placental tissues of the sow.

Aureomycin can be detected in the milk of sows given the antibiotic orally but the amount is small and variable, and does not influence growth rate of suckling pigs.

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EFFECT OF FEEDING CHLOROMYCETIN MYCELIAL MEAL UPON THE GROWTH AND FECAL MICROFLORA OF SWINE

J. F. Elam, R. L. Jacobs, Jean Fowler, Fred Hale and J. R. Couch [1, 2]

Texas Agricultural Experiment Station

Sieburth *et al.* (1951) reported that in view of the inhibitory effect of penicillin and terramycin on *C. perfringens* in the intestinal tract of turkeys and of terramycin in pigs, it appeared possible that these antibiotics promote growth by preventing enterotoxemia.

Antibiotics have been shown to promote growth in pigs (Luecke *et al.*, 1950; Bowland *et al.*, 1950; Carpenter, 1950; Catron *et al.*, 1950; Cunha, 1950; and Nesheim and Johnson, 1950).

Cuff *et al.* (1951) reported that aureomycin, terramycin, and penicillin increased the average daily gains of weaned Duroc pigs but streptomycin, bacitracin and polymixin did not. These workers reported further that the three antibiotics which produced the fastest gains also controlled scouring resulting from an enteritis. These workers reported further that the control of enteritis and scouring was probably the main factor responsible for the more rapid growth.

Catron and co-workers (1950), studying the relationship of nutrition to enteritis, reported significantly faster gains when either 20 milligrams of aureomycin hydrochloride or 100 milligrams of streptomycin (calculated from streptomycin sulfate) were included in an all-plant ration with or without vitamin B_{12} for weanling pigs. However, Speer *et al.* (1951) failed to increase the growth rate of healthy, previously well-fed pigs under clean conditions when either 5 or 10 milligrams of aureomycin hydrochloride were included per pound of ration.

Burnside *et al.* (1950) reported that pigs on the basal ration and the vitamin B_{12} supplemented diet developed diarrhea, but those receiving the APF fortified diet did not. This was attributed to the presence of aureomycin in the APF supplement, since this antibiotic

[1] Departments of Biochemistry and Nutrition, Poultry Husbandry and Animal Husbandry, Texas Agricultural Experiment Station, Texas Agricultural & Mechanical College System, College Station, Texas.

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is known to prevent diarrhea. Schneider and Huang (1950) reported that terramycin increased the rate of growth of pigs and decreased the incidence of scours.

The object of this experiment was to determine the effect of feeding chloromycetin mycelial meal upon the rate of gain and feed efficiency, and to study the effect of chloromycetin upon the chloromycetin-resistant bacteria, yeasts, and anaerobes (clostridia) in the intestinal tract of swine.

Material and Methods

Forty, three-month-old Duroc pigs were divided into five lots of eight pigs each. The pigs were weighed at the beginning of the test and at weekly intervals for the duration of the 13-week test.

The diet of the pigs previous to the beginning of the test consisted of 61 percent ground oats, 10 percent wheat shorts, 8 percent meat scraps, 3 percent alfalfa leaf meal, 1.5 percent oyster shell flour, and 0.5 percent NaCl.

The rations received by the various lots are shown in tables 1 and 2. Lot 1 received the basal ration unsupplemented. Lots 2 and 3 received the basal diet supplemented with vitamin B_{12} and chloromycetin mycelial meal (0.5 percent), respectively. Lot 4 received the basal ration supplemented with vitamin B_{12} and meat scraps and lot 5 received the same supplementation as lot 4 plus chloromycetin mycelial meal (0.5 percent).

Fecal samples were collected once a week for bacteriological analysis. The samples were prepared as described earlier by Elam *et al.* (1951). Clostridia counts were made according to the method of Elam *et al.* (1953). Yeast counts were determined as described by Elam *et al.* (1951). Chloromycetin resistant organisms were determined by plating in nutrient agar containing 100 μg. of chloromycetin per ml.

An analysis of variance of the counts and weights was made.

Results and Discussion

In both lots 3 and 5 the addition of chloromycetin mycelial meal increased, though not significantly, the rate of gain. The addition of chloromycetin mycelial meal to the ration did not result in a significant increase in feed efficiency.

The feeding of this antibiotic increased significantly (1 percent level of probability) the yeast count and the chloromycetin resistant organisms (table 4). Whether or not this increase in these two groups of

TABLE 1. RATIONS RECEIVED THE FIRST FOUR WEEKS OF TEST

Ingredients	Lot No. 1	2	3	4	5
			%		
Ground milo	68.0	68.0	68.0	73.0	73.0
Meat scraps	....	....	....	10.4	10.4
Soybean oil meal	24.0	24.0	24.0	10.4	10.4
Alfalfa leaf meal	6.0	6.0	6.0	5.2	5.2
Limestone	1.5	1.5	1.5	0.5	0.5
NaCl	0.5	0.5	0.5	0.5	0.5
Chloromycetin mycelial meal [1]	....	....	0.5	....	0.5
Vitamin B_{12} (per 100 lb.) (mg.)	....	0.96	....	0.96	0.96

[1] was substituted for an equivalent amount of mixed ingredients—contained 5.79 mg. B_{12} per gram and 4.2 mg. chloromycetin per gram—furnished by Parke Davis & Co.

microorganisms leads to a "sparing" or "synthesis" of certain nutrients or unidentified factors is possible but still unknown.

The feeding of chloromycetin significantly (5 percent level of probability) reduced the total number of clostridia when fed in combination with meat scraps over that of meat scraps alone. The addition of meat scraps to the ration tended to enhance the total number of clostridia. From this it is apparent that the addition of meat scraps provided a very favorable medium for the microorganisms (clostridia) in the intestinal tract of the pig.

TABLE 2. RATIONS RECEIVED FROM THE FIFTH THROUGH THE THIRTEENTH WEEKS OF TEST

Ingredients	Lot No. 1	2	3	4	5
			%		
Ground milo	77.5	77.5	77.5	81.0	81.0
Meat scraps	....	....	....	7.2	7.2
Soybean oil meal	16.4	16.4	16.4	7.2	7.2
Alfalfa leaf meal	4.1	4.1	4.1	3.6	3.6
Limestone	1.5	1.5	1.5	0.5	0.5
NaCl	0.5	0.5	0.5	0.5	0.5
Chloromycetin mycelial meal [1]	....	....	0.5	....	0.5
Vitamin B_{12} (per 100 lb.) (mg.)	....	0.96	....	0.96	0.96

[1] was substituted for an equivalent amount of mixed ingredients.

TABLE 3. THE EFFECT OF FEEDING CHLOROMYCETIN MYCELIAL MEAL UPON THE WEIGHTS AND FEED EFFICIENCY OF SWINE

Lot No.	Supplements to Basal Diet	Initial Weight	Final Weight	Average Daily Gain	Feed per 100 Lb. Gain
			lbs.		
1	None	54.3	192.1	1.51	350.2
2	B_{12}	54.3	197.2	1.57	374.4
3	C.M.M.[1]	54.2	203.5	1.64	344.2
4	B_{12}+meat scraps	54.1	203.5	1.64	330.5
5	B_{12}+meat scraps+C.M.M.	54.3	214.2	1.75	330.2

[1] Chloromycetin Mycelial Meal.

Summary and Conclusions

Weanling pigs were fed an all-vegetable protein diet supplemented with various combinations of meat scraps, vitamin B_{12} and chloromycetin mycelial meal. The addition of vitamin B_{12} to the basal ration did not result in a significant increase in gain or in feed efficiency. Adding chloromycetin mycelial meal to the basal diet did not produce a significant increase in gain and did not cause a significant increase in feed efficiency.

The addition of meat scraps to the diet increased the total number of clostridia and this number was greatly lowered by the addition of chloromycetin. Chloromycetin increased the total count and the

TABLE 4. THE EFFECT OF FEEDING CHLOROMYCETIN MYCELIAL MEAL UPON THE NUMBER OF CHLOROMYCETIN-RESISTANT BACTERIA, YEASTS, AND ANAEROBES (CLOSTRIDIA) IN THE FECES OF SWINE

Lot No.	Treatment	Chloromycetin-Resistant Bacteria	Yeasts	Clostridia Isolates
1	None	1775	235	13,945
2	B_{12}	1225	135	12,995
3	C.M.M.[1]	21,700*	12,250*	13.220
4	B_{12}+meat scraps	2575	435	840,120
5	B_{12}+meat scraps+C.M.M.	20,160*	11,535*	40,295**

[1] Chloromycetin Mycelial Meal.
* Significant at the 1% level of probability.
** Significant at the 5% level of probability.

number of chloromycetin resistant organisms. This increase in these microorganisms possibly could lead to a "sparing" or "synthesis" of certain nutrients or unidentified factors.

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THE EFFECT OF BACITRACIN IMPLANTS ON WEANING WEIGHTS AND SUBSEQUENT FEED LOT PERFORMANCE OF TWO-DAY OLD PIGS [1]

T. W. Perry, G. W. Thrasher and W. M. Beeson [2]

Purdue University Agricultural Experiment Station

ORALLY administered antibiotics, at adequate levels, have been proven as growth stimulants for growing swine. However, there arises the problem of administering antibiotics to pigs from birth to two weeks before they begin to consume appreciable quantities of dry feed. An approach to this problem has been through the use of implants or injections. Noland *et al.* (1952) reported an increased weaning weight at 56 days of three pounds for pigs which had been implanted with 1000 units of bacitracin at two days of age as compared with controls. Oldfield and Hale (1952) reported an increased weaning weight of three and one-half pounds for pigs at 56 days of age which had been intramuscularly injected with 280 mg. of procaine penicillin G in sesame oil when the pigs were three days old.

The experiment reported in this paper was designed to study further the effect of bacitracin implants on the weaning weight and subsequent feed lot performance of pigs implanted at two days of age.

Experimental

Phase I

Six litters of crossline pigs were used for this experiment. One-half of the pigs in each litter was randomly selected and implanted with a single pellet containing 22.5 mg. of bacitracin. The pellet was implanted subcutaneously posterior to the right ear. The sows and litters were moved to pasture 10 days after the pigs were born. The pigs had free access to a well-balanced creep ration which contained no antibiotic (table 1). Prior to weaning, no antibiotic was available to the pigs except for the pellet implant contained in the treated pigs. The pigs were weighed individually at weekly intervals, weaned at six weeks of age and then treated as described in the second phase of this experiment.

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[2] The authors are grateful to Doctor E. J. Turman and the Swine Breeding Laboratory for providing the pigs and caring for the pigs until weaning.

Phase II

As each litter of pigs was weaned it was placed in paved lots to be fed out to market weight. One-half of the pigs in each litter which had not been implanted and one-half of the pigs which had been implanted were fed the basal ration listed in table 2 (Lots I and III respectively). Similarly, one-half which had not been implanted and one-half which had been implanted were fed the basal ration

TABLE 1. COMPOSITION OF CREEP RATION

(19.68% Crude Protein)

Component		Percent of Ration
Rolled oats		52.50
Ground yellow corn		24.15
Purdue Supplement 5		20.00
Soybean oil meal	40	
Fish meal	20	
Meat and bone scraps	20	
Cottonseed meal	10	
Alfalfa meal	10	
40–40–20 mineral mix		2.50
Steamed bone meal	40	
Ground limestone	40	
Iodized salt	20	
Concentrated cod-liver oil		.75
Choline chloride		.10
		100.00[1]

[1] The above ration was fortified with the following vitamins per pound of ration: riboflavin 1.6 mg., calcium pantothenate 9.0 mg., niacin 10.0 mg., vitamin B_{12}

plus 7.5 mg. aureomycin hydrochloride per pound total ration (Lots II and IV). The pigs were weighed at two-week intervals and as each pig reached 200 pounds liveweight it was removed from the experiment.

Results and Discussion

Control pigs were as heavy at six weeks as littermates which had been implanted with bacitracin (33.1 lb.). Noland *et al.* (1952) reported a three-pound increase in fifty-six-day weaning weight for pigs which had been implanted with a bacitracin pellet of the same potency. However, the fifty-six-day weaning weight of control animals in the work reported by Noland and co-workers was but 26.08 pounds whereas the 33.1 pound weaning weight of the control pigs in the experiment reported in this paper was at 42 days. Possibly factors such as environment, breeding, type of ration and inherited growth rate of pigs had an effect on the difference in response.

During the forty-two-day nursing period the pigs consumed an average of 7.3 pounds of creep ration per pig (table 1).

The implantation of bacitracin pellets in two-day old pig had no effect on their subsequent feed lot performance. Pigs which had not been implanted and which received no antibiotic in their post-weaning ration (Lot I) grew just as rapidly (1.42 lb. per day) as pigs which had been implanted and which received a similar post-weaning ration (Lot III—1.38 lb. per day). Similarly, pigs which were not implanted

TABLE 2. COMPOSITION OF BASAL RATION (PHASE II)
(16.28% Crude Protein)

Component	Percent of Ration
Ground yellow corn	78.65
Soybean oil meal	10.50
Meat scraps	8.40
Alfalfa meal	2.10
Concentrated cod-liver oil	.25
Vitamin B_{12} supplement	.10
	100.00[1]

[1] The above ration was fortified with the following vitamins per pound of ration: riboflavin 0.8 mg., calcium pantothenate 4.5 mg., niacin 5.0 mg.
A free choice mineral mixture was fed (steamed bonemeal 40, ground limestone 40, iodized salt 20).

and which received a post-weaning ration containing 7.5 mg. aureomycin hydrochloride per pound total ration (Lot II) grew just as rapidly (1.73 lb. per day) as previously injected pigs on a similar ration (Lot IV—1.67 lb. per day). The aureomycin produced a highly significant ($P<.01$) growth response over the controls and improved the feed efficiency. It has been observed in other work at this station that greater growth response from the feeding of antibiotics was obtained when the administration was begun at early ages and at lighter weights (Perry and Beeson, 1952).

Summary

The subcutaneous implantation of a pellet containing 22.5 mg. bacitracin in two-day old crossline pigs had no effect on forty-two-day weaning weights or subsequent feed lot performance whether or not the post-weaning ration contained 7.5 mg. aureomycin hydrochloride per pound total ration.

TABLE 3. THE EFFECT OF BACITRACIN IMPLANTS ON WEANING WEIGHTS AND SUBSEQUENT FEED LOT PERFORMANCE OF TWO-DAY OLD PIGS

(Six Litters)

Phase I (42 Days)

Item	Group I Control	Group II Implanted
Number of pigs	23	25
Av. birth wt., lb.	3.01	2.86
Av. 42-day wt., lb.	33.10	33.10
Av. daily gain, lb.	0.61	0.62

Phase II

	Not Implanted at 2 Days		Implanted at 2 Days	
Item	Lot I No Antibiotic	Lot II 7.5 Mg. Aureomycin	Lot III No Antibiotic	Lot IV 7.5 Mg. Aureomycin
Number of pigs	12	11	12	13
Av. initial wt., lb.	33.1	33.1	32.9	33.3
Av. final wt., lb.	199.0	200.5	198.0	199.2
Av. daily gain, lb.	1.42	1.73[1]	1.38	1.67[1]
No. days from weaning to reach 200 lb.	117	98	120	99
	Daily Feed Consumption			
Corn, lb.	3.69	4.21	3.52	4.09
Protein suppl., lb.	0.78	0.94	0.74	0.88
Minerals	0.02	0.01	0.01	0.01
	Feed per 100 Pounds Gain			
Corn, lb.	260.0	243.5	255.1	244.1
Protein suppl., lb.	54.8	54.3	53.2	52.8
Minerals	1.4	0.7	0.7	0.6

[1] Difference in gain between Lots I and II and between Lots III and IV was highly significant ($P<.01$). LSMD, 1% level is 0.18 lb.

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THE EFFECT OF INTERMITTENT ADMINISTRATION OF AUREOMYCIN TO GROWING-FATTENING SWINE [1]

JOSEPH E. BURNSIDE,[2] R. H. GRUMMER, P. H. PHILLIPS and G. BOHSTEDT

University of Wisconsin [3]

THE growth-stimulating properties of antibiotics are well established for monogastric animals and, in a restricted sense, for ruminants. That periodic feeding or intermittent feeding is beneficial is not very well established. It is a rather common practice among swine producers to purchase antibiotic concentrates in small quantities and use them irregularly in growing-pig rations.

Therefore this experiment was initiated to study the effect of 3- and 10-day intermittent feeding and various combinations of periodic feeding of aureomycin.

Experimental Procedure

Eighty-one weanling pigs were stratified according to sex and randomized into nine lots of nine pigs each, four males and five females. The ration consisted of corn, soybean oil meal, dehydrated alfalfa leaf meal, and trace-mineralized salt. The initial crude protein content of the ration was 20 percent; when the average weight of each lot of pigs reached 75 pounds, the protein content was reduced to 17 percent, and again when the average weight of each lot reached 125 pounds, it was reduced to 14 percent. Crystalline aureomycin [4] was included in the feed at a rate of 20 milligrams per kilogram of ration. The evaluation of treatments was based on rate and efficiency of gain and gross appearance of the animals. The animals were housed on concrete and cared for in accordance with accepted animal husbandry practices; feed and water were supplied *ad libitum*.

The assignment of lots was as follows: lot 1, basal; lot 2, basal plus continuously-fed aureomycin; lot 3, basal plus aureomycin fed intermittently for 3-day periods, and lot 4, aureomycin fed intermittently for 10-day periods. The intervals for periodic feeding were

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station, Madison.

[2] Present address: Georgia Coastal Plain Experiment Station, Department of Animal Disease, Tifton, Georgia.

[3] Departments of Animal Husbandry and Biochemistry, Madison, Wisconsin.

[4] Lederle Laboratories Division of American Cyanamid Company, Pearl River, N. Y.

arrived at by dividing the growing-fattening period into thirds on the basis of initial and final weight; i.e., 39 to 210 pounds. The first one-third ended at 96 pounds, and second one-third at 153 pounds. The pigs in lot 5 received aureomycin for the first two-thirds, lot 6 the last two-thirds, and lots 7, 8, and 9 for the first, second, and third one-third, respectively.

Results and Discussions

Within about 20 days after the experiment was begun, it became apparent that the pigs were succumbing to a natural outbreak of bloody dysentery. Rather than terminate the experiment, it was allowed to continue because bloody dysentery is one of the more economically important swine diseases and because all lots seemed to be affected equally at the onset of the symptoms. By the 59th day the mortality rate had been high and the condition of the remaining animals was critical in all lots not receiving aureomycin. Therefore lots 6, 8 and 9 were switched to rations containing the antibiotic supplement although their mean weights were short of the 96 pounds, the weight which was originally planned to terminate the first one-third of the experiment.

The experiment now resolved itself into two parts, the efficacy of aureomycin in combating bloody dysentery and the effect the antibiotic had on the rate of gain of the surviving animals. Table 1 gives a summary of the growth data and death losses. The two deaths in lot 3 and one in lot 5 could be attributed to bloody dysentery in the presence of aureomycin; there were no deaths in any of the other lots after aureomycin supplementation was started. A test of the death losses by the chi square method showed that under the conditions of this experiment, the feeding of aureomycin significantly reduced the death loss due to bloody dysentery. It has been observed by numerous workers that antibiotics in general are effective in the control of natural outbreaks of bloody dysentery. Carpenter and Larson (1952), in an experiment specifically designed to test the effect of antibiotics alone and in conjunction with various arsenicals, showed that aureomycin, terramycin, penicillin, and bacitracin were effective in curing and preventing the recurrence of bloody dysentery. In that experiment the pigs were artificially infected by feeding filtrates and slurries secured by homogenizing the colons from naturally infected pigs.

Each of the pigs that succumbed to the disease in the present experiment developed anorexia and exhibited various degrees of lassi-

TABLE 1. SUMMARY OF GROWTH DATA AND DEATH LOSSES [1]

	Lot Number and Treatment								
Item	1 Basal	2 Basal+ Aureo. Cont.	3 Basal+ Aureo. 3-Day Inter.	4 Basal+ Aureo. 10-Day Inter.	5 Basal+ Aureo. 1st ⅔	6 Basal+ Aureo. Last ⅔	7 Basal+ Aureo. 1st ⅓	8 Basal+ Aureo. 2nd ⅓	9 Basal+ Aureo. Last ⅔
No. days	166	126	131	160	143	139		153	137
At end of experiment:									
Living	6	9	7	9	7	5			4
Dead	3	0	2	0	2	4		3	5
Av. initial wt., lb.	38.6	40.7	40.3	38.2	38.2	38.4	[illegible]	39.3	38.4
Av. final wt., lb.	212.4	210.1	210.7	212.3	211.9	211.6	210.2	210.8	211.8
Av. daily gain, lb.	1.06	1.34	1.30	1.09	1.21	1.25	1.23	1.11	1.26

[1] $X^2=16.64$ for living and dead pigs, i.e., treatment had a significant effect on livability of pigs.
$F=1.41$ for differences in rate of gain, i.e., treatment did not have a significant effect.

tude; an extreme weight loss was evident and was due to the dehydrating effects of the diarrhea (i.e., several 60 and 70 pound pigs lost 18 pounds in 7 days). The fecal material of the infected pigs was extremely watery and contained varying amounts of blood and heavy mucus. In some cases the mucus was so thick that it resembled a thin membrane. Three to four pigs in each of the aureomycin lots became emaciated and lost weight, but in each instance, except the cases previously noted, the pigs lost all outward signs of the disease and after about 4 to 8 days were gaining at a normal rate and appeared normal in every respect. These data would indicate that, when aureomycin is mixed in the feed at a level of 20 milligrams per kilogram of ration, it not only gives an increased growth rate but is instrumental in protecting growing-fattening pigs from natural infections of bloody dysentery; this is in the absence of arsenicals

TABLE 2. SUMMARY OF POOLED DATA FOR THE FIRST 55 DAYS

Lot	Av. Daily Gain
	lb.
First 55 days:	
Control lot	0.55
Continuously-fed lot	0.85*

* Significant at 1% level.

in the drinking water and would be the condition encountered under feed-lot conditions.

When the growth data were analyzed as presented in table 1, the gains of the treated lots were not significantly different from those of the controls. It is suggested that the non-significance of the growth data, statistically speaking, is due to the loss of animals and the extreme within-lot variation of the average daily gains in all lots because of the aggravating effect of the disease.

The data from lots 1, 6, 8 and 9 were pooled for the first 55 days and used as the controls against the pooled data from aureomycin lots 2 and 5 for the same period; this would cover approximately the first one-third of the experiment. These comparisons are presented in table 2.

The pooled data show that the continuous feeding of aureomycin for the first 55 days resulted in gains which were significantly faster than those of the controls. Pratt and Dufrenoy (1949) suggest that intermittent feeding of aureomycin or similar antibiotics may be more desirable than continuous feeding because intermittent feeding permits

regrowth of surviving organisms which, being in a more active metabolic state, are more sensitive to the action of the antibiotic. Relatively speaking, aureomycin has little effect on fully grown or metabolically inactive cultures; it is most effective against rapidly multiplying organisms. They caution that the intervals should be such that regrowth does not nullify the benefits of the preceding dose.

It is interesting to note the similarity of the gains of lots 2 and 3, and 1 and 4. The gains of the animals in lots 1 and 8 were very similar, as were the gains of the pigs in lots 6 and 9. The gains of these latter two lots were considerably higher than the gains of lot 1.

When the data are arbitrarily pooled as in table 3, another interesting comparison can be made. These data suggest that, regardless of the time of aureomycin feeding, the gains of the surviving pigs were approximately the same (i.e., groups C and D), but aureomycin fed continuously produced the maximum gains. The data for deaths tell a different story. A test of significance with the chi square method shows that the death rate in groups B and D is significantly lower than the death rate in groups A and C. This would suggest that the aureomycin should be fed as in groups B and D, i.e., at the beginning of the feeding period rather than toward the end of it. Thus it seems that under these conditions aureomycin increases gains when fed during the first part as well as the last part of the experiment, but to realize the full benefits it must be fed during the first part so the bloody dysentery can be controlled.

Berg *et al.* (1950), working with chicks up to 8½ weeks of age, found that the deletion of aureomycin at 4½ weeks gave a growth rate which was a little less than the basal lot for the last half of the period. When the antibiotic was fed the last half of the period, the growth rate was slightly better than that of the continuously-fed lot. Although the over-all gain was in favor of the continuously-fed lot due to the early rapid gains, essentially the same results were observed when vitamin B_{12} and aureomycin were used. They concluded that the beneficial effects of antibiotics were limited to the time interval during which the material was fed.

The deaths in lots 3 and 5, plus the fact that several pigs in each lot showed visible effects of the disease, suggest that the aureomycin was exerting a bacteriostatic effect on the causative agent for the disease and was not sterilizing the intestine with regards to this organism. Furthermore, when the antibiotic was removed, the suppressed organisms tended to again multiply and become noticeably

TABLE 3. DATA POOLED ACCORDING TO TIME OF AUREOMYCIN FEEDING

Group A No Aureo.			Group B Cont. Aureo.			Group C No Aureo. at Beginning; Aureo. Later			Group D Aureo. at Least at Beginning		
Lot No.	Gain	Deaths	Lot No.	Gain	Deaths	Lot No.	Gain	Deaths	Lot No.	Gain	Deaths
	lb.			lb.			lb.			lb.	
1	0.91	3	2	1.34	0	6	1.25	4	3	1.30	2
..	....	..	..	....	..	8	1.11	3	4	1.09	0
..	....	..	..	....	..	9	1.26	5	5	1.21	2
..	....	..	..	....	..	..	....	..	7	1.23	0
Av.	0.91	3	Av.	1.34	0	Av.	1.21	4	Av.	1.21	1

$X^2=12.9$ significant at the 1% level for differences in death rate.

pathogenic. Evidence of this fact is shown in the data presented in table 4. This would tend to agree with the work of Wallace *et al.* (1951) where they fed swine an aureomycin-supplemented ration from weaning to 100 and 120 pounds and thereafter the omission of the antibiotic for the remaining part of the growing-fattening period caused the growth rate to be sharply reduced.

In this table each period of aureomycin feeding was contrasted to the basal for the appropriate period. In both lots, regardless of the time fed, aureomycin increased the gains during the time interval it was fed. The deletion of the antibiotic caused an immediate regression in the rate of gain; this effect has been noticed by other researchers as previously discussed.

TABLE 4. AVERAGE DAILY GAINS FOR LOTS 5 AND 8 AS COMPARED TO LOT 1

Period of Experiment	Lot 1 No Aureo. Any Time	Lot 5 Aureo. 1st ⅔ of Exp.	Period of Experiment	Lot 1 No Aureo. Any Time	Lot 8 Aureo. 2nd ⅓ of Exp.
	lb.	lb.		lb.	lb.
1st ⅔	0.73	1.19	1st ⅓	0.39	0.56
Last ⅓	1.42	1.14	2nd ⅓	1.12	1.59
.....	....	....	3rd ⅓	1.50	1.12

Summary and Conclusions

Twenty milligrams of crystalline aureomycin per kilogram of ration when fed continuously during the growing-fattening period controlled a natural outbreak of bloody dysentery among swine and significantly reduced the deaths due to this disease.

The same level of aureomycin supplementation at 3- and 10-day intervals was less effective in controlling the early deleterious influence of the bloody dysentery.

Death losses were lower in the lots receiving antibiotic during the early period of the trial than in those lots receiving the supplement during the middle and late periods. However, the over-all average rates of daily gain were not significantly different.

Deletion of the antibiotic from the ration during the middle or latter part of the feeding caused a concomitant decrease in rate of gain.

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THE EFFECTS OF GENETIC DIVERSITY AND PERFORMANCE OF INBRED LINES *PER SE* ON HYBRID VIGOR IN SWINE [1]

DAVID C. ENGLAND and LAURENCE M. WINTERS

University of Minnesota

THE occurrence of heterosis in crosses of non-inbred breeds of swine has been demonstrated by various workers (Winters *et al.*, 1935; Hutton and Russell, 1939; Lush *et al.*, 1939; Robison, 1946, 1948, and others). Further advancement of research in crossbreeding swine was accelerated through the establishment of the Regional Swine Breeding Laboratory in 1937. The Laboratory, in cooperation with several state experiment stations, including Minnesota, initiated programs designed to explore the possibility of developing genetically improved, purified, and diverged strains or lines of swine. The ultimate purpose of the development of the lines included in the present study was for their utilization in crosses to provide still higher levels of crossbred performance in commercial swine production (Winters *et al.*, 1948).

Reports by Winters *et al.* (1944), Robison (1944), Dickerson *et al.* (1946), Sierk and Winters (1951), Chambers and Whatley (1951), Hetzer *et al.* (1951) and others establish that heterosis regularly occurs from the crossing of inbred lines of swine, both within and between breeds. In view of these findings and the increasing use of inbred stocks for commercial production of crossbred pigs, it is pertinent to determine the relationship of various practical factors to the amount of heterosis expressed in crosses of inbred lines of swine. The purposes of the present study, therefore, are to determine (1) the amount of heterosis expressed in crosses as affected by (a) genetic diversity of parental stocks, (b) the level of performance of parental stocks; (2) the relative amounts of heterosis expressed by various components of vigor; and (3) the relationship of these factors to securing maximum amounts of heterosis in commercial swine production.

[1] Paper No. 2973, Scientific Journal Series of the Minnesota Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U. S. Department of Agriculture. This paper is condensed from a thesis submitted by the senior author to the Graduate Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of doctor of philosophy.

Source of Data and Method of Analysis

The performance records of 2332 crossbred pigs have been analyzed. These data accumulated during the period 1941–1951 in the overall swine breeding program of the University of Minnesota in cooperation with the Regional Swine Breeding Laboratory. Only spring-farrowed gilt litter records were used. All of the parental lines involved have been developed by flexible systems of inbreeding and selection. Selection pressure has been rigorous and continuous for factors of economic importance; the system of selection used is flexible enough to permit the placement of major emphasis on the character in greatest need of improvement. The crosses were produced at five different stations; in some cases one or both parental lines were maintained at different stations than the crosses. Insofar as was possible, comparisons have been made on a within-year, within-station basis; where this was not possible, the average performance over a period of years was used for the line not kept at the same station as the cross. Most crosses have been produced in more than one year; comparisons are between weighted averages. It is believed that these techniques in addition to the sampling nature of data gathered over an 11-year period at five different stations result in an aggregate data free of consistent bias.

The performance of the crosses has been compared to the mean parental performance. Five factors of performance were used, namely, number born alive, percent survival to weaning (56 days), individual weaning weight, and rate and efficiency of post-weaning gain. Kristjansson's correction (Fine, 1951) was used to correct feed efficiency to a basis of 35 pounds initial weight and 200 pounds final weight. The difference between crossed and mean parental performance for each trait has been expressed as a percentage of the mean parental performance. These five percentages have been added and divided by five to provide an average overall comparison.

The crosses have been divided into various groups according to expected genetic divergence. The narrow groups of single and crisscross crosses are crosses of lines within the Poland China breed; the medium crosses are between Minnesota No. 2 and various Poland China lines. The wide groups of single and crisscross crosses are between Minnesota No. 1 and various Poland China lines and between Minnesota No. 1 and Minnesota No. 2. In the rotational crosses, both the narrow and wide crosses are composed of continuous crosses of Minnesota No. 1, Minnesota No. 2, and Poland China lines. The

difference between the wide and narrow in this case is merely the pattern of mating. For example, the continuous cross Minnesota No. 1×(#2×P.C.×1) is classified as a wide cross, whereas the continuous cross Minnesota No. 2×(P.C.×#1×#2) is classified as a narrow mating because of the relationship between the Minnesota No. 2 and the Poland China lines. Any gilt mated to a boar of the line from which her own sire came constitutes a narrow mating; any gilt whose sire was a Minnesota No. 2 when mated to a Poland China boar (or vice versa) constitutes a narrow mating.

Statistical tests of significance have been made only for those traits where the individual pig rather than the individual litter is the unit of comparison. Each group, according to genetic diversity and the system of crossing, is composed of a statistically small sample of litters from each of several line crosses. Since these lines differ in their level of performance with respect to the various traits, they cannot be pooled for the calculation of tests of significance of differences between crosses and weighted parental averages. Nevertheless, it is legitimate to classify them into the groups as set up for determination of the effect of genetic diversity since these crosses as grouped are expected to be homogeneous with respect to genetic diversity.

Under the system of comparison used, the crosses of high performing lines are penalized in comparison to crosses of lower performing lines insofar as percent superiority over parental averages is concerned. This is so because of the difference in the numerical value of the denominator of the fraction to be expressed as a percentage. To eliminate this bias, crosses of equal genetic diversity have been compared to a standard of performance calculated in the following manner: the average performance of four Poland China lines, all of which have been used in crosses with the Minnesota No. 1 and Minnesota No. 2, has been obtained. The crosses of the Minnesota No. 1 and each of the four lines have been compared to the mean of the performance of the Minnesota No. 1 and the average performance for the four Poland China lines. Crosses of the Minnesota No. 2 and each of the Poland China lines have been handled similarly, using the performance of the Minnesota No. 2 instead of the Minnesota No. 1. Crosses of Minnesota No. 1—Minnesota No. 2 are compared to the same standard as a Minnesota No. 1—Poland China line cross, since it is expected that genetic diversity is equal in these two kinds of crosses. Essentially this method establishes the relative performance of various lines by expressing them as a percentage of

an impartial standard, and then, with genetic diversity held constant, establishes the relative performance of these lines in crosses by comparing each cross against an appropriate impartial standard. This then allows a comparison of various lines in crosses with each cross

TABLE 1. A COMPARISON OF THE EFFECT OF DIFFERENT WIDTHS OF GENETIC DIVERSITY ON PERCENT SUPERIORITY OF PERFORMANCE OF CROSSES OVER PARENTAL AVERAGES

Cross[1]	No. of litters	Number born alive	Percent survival	Weaning weight/pig[2]	Postweaning daily gain[2]	Feed/cwt. gain[3]	Mean[4]
Single							
Narrow	62	0.97	8.88	11.29	8.33	−2.47	5.40
Medium	30	25.18	1.24	15.58	10.00	−6.17	9.17
Wide	49	−5.33	20.40	33.51	20.32	−1.40	13.50
Mean		6.94	10.17	20.13	12.88	−3.35	9.35
Crisscross							
Narrow	31	6.15	15.45	19.00	16.67	−0.93	11.27
Medium	24	9.41	7.41	21.79	8.73	+0.31	9.53
Wide	60	30.16	18.94	22.36	10.82	−8.38	14.78
Mean		15.24	13.93	21.05	12.07	−3.00	11.86
Rotational							
Narrow	24	11.96	15.65	14.16	7.30	−5.88	8.64
Wide	38	31.71	14.57	15.98	11.11	−7.43	13.19
Mean		21.84	15.11	15.07	9.20	−6.66	10.91

[1] See text for description of narrow, medium and wide classifications.

[2] Of the 7 different non-reciprocal line crosses composing the narrow single group, 5 were significant at the 1% level for heavier weaning weight; 4 were significant at the 1% level for faster postweaning gain. In the medium single crosses, two of four groups were significant at the 1% level for both traits; 1 was significant at the 5% level for both traits. All 5 groups of wide single crosses were significant at the 1% level for both traits.

Of the 4 groups comprising narrow continuous crosses, 2 were significant at the 1% level for heavier weaning weight, and one was significant at the 1% level for postweaning rate of gain. Both groups of medium continuous crosses were significant at the 1% level for heavier weaning weight; one was significant at the 1% level and the other at the 5% level for postweaning rate of gain. All 4 groups of wide continuous crosses were significantly superior for both traits at the 1% level.

All four groups of narrow rotation crosses were significantly heavier at weaning at the 1% level; 3 groups had significantly faster postweaning growth at the 1% level. In the wide rotation cross, 3 of 4 groups were significant at the 1% level for both traits; the other group closely approached the 5% level. Of the 34 groups of crosses comprising the eight classifications in Table 1, 32 groups excelled the parental means for these two traits. The consistency of superiority indicates that most differences are real, though not necessarily significant.

[3] Corrected to a basis of 35 lbs. to 200 lbs.

[4] Unweighted.

compared to an impartial standard. The relative performance of lines *per se* and their relative performance in crosses can thus be compared.

Results

Table 1 demonstrates the close agreement found in this study between increased genetic diversity of parents and increased heterosis in the cross. The average superiority of crisscross and rotational

crosses over single crosses in general indicates that maximum utilization of heterosis is achieved only with the use of cross-bred females. That genetic diversity is as essential in continuous crosses as in single crosses is indicated by the relative superiority of the different widths of crosses within the crisscross and rotational crosses. This same point is further emphasized in a comparison of the wide rotation cross with the average of wide and medium crisscross crosses. This latter comparison is justified since the wide rotational cross contains all three breeds and thus some limitations on genetic diversity (due to the genetic relationship between the Minnesota No. 2 and the Poland China lines), whereas the breeds involved in the wide crisscross carry no particular relationship to each other. In continuous crisscrosses, approximately 67 percent of the inheritance (on the average) is in each generation from the line of the sire; in continuous three-line rotations, only about 57 percent of the genes are derived from the line of the sire each generation. It is thus to be expected that continuous three-line crosses will exhibit more heterosis than continuous two-line crosses.

Performance with respect to feed/cwt. gain in this study is not in accord with most published reports. There is some reason to doubt that the observed increased feed requirement of the crosses is genetic in origin. Almost all of the pigs in four of the five groups having highest feed requirement were raised at one station; it may be that station effects have not been adequately removed in the feed analysis. An analysis of the data within crossbred groups revealed that the fastest-gaining one-half of the groups had an average daily gain of 1.57 pounds and required 333 pounds of feed/cwt. gain; the slower growing one-half of the group gained 1.44 pounds daily and required 340 pounds of feed/cwt. gain. These results indicate a positive association between rate of growth and efficiency of feed utilization within the crossbred population. It is thus believed that factors other than genetic associations are responsible for the higher feed requirement of these crosses over their parental averages.

Another possibility is that feed efficiency is so confounded with various physiological factors as to make genetic interpretation not only difficult but impossible until the relationship between feed efficiency and various physiological factors is better understood. It appears clear that heavy feeding has a deterring effect on efficiency of digestion; deficient feeding necessitates that an increased percentage of the feed be used for maintenance, and heavy feeding leads

to increased fat deposition which requires more feed per unit of gain. These may be only some of the factors which complicate an intelligent interpretation of the factors involved in breeding for lowered feed requirements.

Table 1 also indicates the relative amounts of heterosis expressed by the various components of vigor.

Uniformity of performance is of distinct advantage to the swine producer. The lack of uniformity in certain superficial traits, such as color, for example, in some swine crosses has at times been interpreted as a general lack of uniformity among crossbred pigs. Table 2

TABLE 2. MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION FOR THREE PERFORMANCE TRAITS IN GILT LITTERS

Average of:	Weaning weight			154 day weight			Daily rate of gain[1]		
	$\bar{x}$	s	Cv	$\bar{x}$	s	Cv	$\bar{x}$	s	Cv
Inbred lines	30.51	6.25	20.75	165.69	21.69	13.27	1.38	.2471	18.24
Single crosses	37.01	7.06	19.43	190.91	21.40	11.35	1.57	.1763	11.41
Continuous crosses	35.20	6.72	18.62	179.90	18.91	10.26	1.47	.1637	10.87
Hybrid male x hybrid female	37.45	6.77	18.01	197.70	20.98	10.75	1.63	.1872	11.67

[1] 56 to 154 days.

contains the means, standard deviations, and coefficients of variation of the parental lines and various kinds of line crosses for three performance traits. An increased relative uniformity of systematically produced crossbred pigs is indicated. Phillips *et al.* (1942), Hilder and Fohrman (1947), and Sierk (1948) have observed similar results with crosses in beef cattle, dairy cattle, and swine, respectively. The crosses in the present study show less relative variation in performance than the parental lines; continuous crosses of inbred sires on crossbred dams consistently show less relative variation than single crosses of inbred lines. It may be of interest to note that the use of crossbreds as both parents resulted in relative variation essentially equal to that found in the parent inbred lines.

With a given amount of increase a cross of two poorly productive lines will show a higher percentage increase than will a cross with the same actual amount of increase from higher performing lines. This is a deceptive situation since the latter is actually the more economically desirable cross. To eliminate the bias arising from this basic condition and to determine the relationship of performance of

inbred lines *per se* to the performance of their crossbred offspring, table 3 was calculated using the method explained under Source of Data and Method of Analysis. Table 3 shows a close agreement between the performance of a line as such and the performance of that line in crosses.

TABLE 3. RELATIVE PERFORMANCE, IN PER CENT (BASED ON IMPARTIAL STANDARDS)[1] OF VARIOUS LINES AND CROSSES

Group	Number of litters	Number born	Per cent survival	Weaning weight	Daily gain	Average of 4 factors
A Line[2]		102.10	108.59	103.70	114.71	107.28
V Line[2]		109.16	101.11	102.74	104.41	104.36
C Line[2]		90.84	98.49	95.88	102.21	96.86
M Line[2]		97.60	91.80	97.74	79.41	91.64
#2 x A[3, 4]	8	112.68	103.29	118.32	120.44	113.68
#2 x V	16	120.56	103.08	117.42	110.22	112.82
#2 x C	14	111.69	134.00	108.59	108.76	115.76
#2 x M	15	109.86	105.30	118.88	95.62	107.42
#1 x A	19	118.51	127.34	131.75	113.24	122.71
#1 x V	21	86.88	125.80	128.02	115.44	114.04
#1 x C[4]	13	80.80	137.56	125.58	118.38	115.58
#1 x M	33	98.76	115.31	130.09	108.82	113.24
#1 x #2	23	115.47	132.87	133.72	113.24	123.82
All A crosses		115.60	115.32	125.04	116.84	118.20
All V crosses		103.72	114.44	122.72	112.83	113.43
All C crosses		96.24	135.78	117.08	113.57	115.67
All M crosses		104.31	110.30	124.48	102.22	110.33

[1] Derivation of standard is described in section on Methods of Analysis.

[2] Performance of each of these lines is expressed as a percentage of the average performance of all four.

[3] Performance of this cross is compared to the mean of the average performance of the Minn. #2 and the average performance of the four Poland China lines. The same is true for the crosses of the Minn. #2 and each of the other Poland China lines. Crosses of the Minn. #1 and each of the Poland China lines are similarly compared except that the performance of the Minn. #1 is substituted for the performance of the Minn. #2. Minn. #1 x Minn. #2 crosses are compared to the same standard as crosses of Minn. #1 x Poland China lines since genetic diversity is expected to be equal in these types of crosses.

[4] Single crosses only.

Discussion

Analysis of the data in the present study in regard to genetic diversity reveals that in general increased genetic diversity of crosses results in increased superiority of performance of these crosses over parental averages. In so doing, this study is in agreement with those by numerous other workers. Analyses of data in the present paper suggest that three or more lines in continuous crosses stimulate higher superiority of crossbred performance over parental averages than do only two lines through maintenance of greater genetic diversity of the cross. It is to be expected that the sampling nature of inheritance

due to segregation, independent assortment and random recombination prevents the accumulation of higher levels of favorable genes *per se* from three or more lines than from only two lines where crossbred gilts are used as dams in each generation. The increased efficiency appears to be that which occurs from increased opportunity for interaction between unlike alleles and gene combinations.

The data in table 1 indicate a greater heterotic effect in preweaning than in postweaning traits. This is in agreement with other experimental results since in general the depressing effects of inbreeding have been more severe for fertility and survival than for growth characteristics.

There are some indications that the pig's own degree of inbreeding may be of more importance than that of its dam in regard to the effect upon fertility and survival. Comstock and Winters (1944) found the regressions of litter size on inbreeding of dam and litter respectively to be $-.02 \pm .016$ and $-.032 \pm .018$. The corresponding partial regressions were -0.009 and -0.028. Winters *et al.* (1944), Dickerson *et al.* (1946), Chambers and Whatley (1951) and Hetzer *et al.* (1951) have reported from 4.26 to 13.64 percent increase in number of pigs born to inbred gilts when bred to boars of a different line. This entire increase must be credited to the genotype of the pig and points to a marked influence of the individual's own genotype on its prenatal survival. It may also indicate that the effects of inbreeding are progressively more severe as the stage of measurement moves progressively toward the beginning of zygotic life. From a comparison of the heterosis expressed in number of pigs born alive in single versus continuous crosses, it appears that actual ovulation rate as well as prenatal survival has been increased.

It will be noted in table 2 that the average relative variation within each inbred line is greater than that of single crosses which in turn is greater than that for continuous crosses. Since the statement is frequently made that inbreeding leads to uniformity and crossbreeding leads to variability, the above findings may need to be examined. The following points seem pertinent: (1) variation is due not only to genotype but to environment as well; (2) early generations of inbreeding induce wide genetic variation, within the limits of the available heterozygosity, due to increased opportunity for divergent combinations to occur. This basic effect occurs with each generation of inbreeding but soon becomes of less magnitude within any line with succeeding generations due to a decrease in remaining hetero-

zygosity. (3) *Inter se* crossing in generations beyond the first cross is expected to lead to variation due to lack of homozygosity. However, in all of the crosses in this study, except those in which hybrid males were used on hybrid females, the sire was inbred and inevitably transmitted a relatively uniform inheritance to each of his offspring, thereby providing a stabilizing and equalizing influence on performance. (4) The inbred lines used in this study were developed under intense selection for the same characters of economic importance, thus retaining, relatively speaking, only alleles of high production potential. It seems logical, therefore, that having been subjected to similar selection pressure but being of different genetic constitution these lines have, through inbreeding, fixed different alleles of high production potential for these various characters. If this is true, then it seems reasonable to expect that the use of even hybrid boars on hybrid females would produce pigs of various genotypes, but all with relatively high growth potential and relatively low variation due to the inheritance of desirable genes and the equalizing influence of heterosis on reaction to environment. Various genotypes could thus produce similar phenotypes. (5) Since performance is controlled by many genes, chance combinations would lead to a majority of intermediate and only a minority of extreme genotypes.

It is the authors' opinion that the economics of pork production demand that inbred lines be in themselves highly productive if they are to make a maximum contribution to the swine industry. The data in table 3 indicate that in order to achieve maximum heterotic stimulation, it is necessary to have lines which in themselves are highly productive. Such lines have a relatively high base of performance from which the heterotic stimulus from crossing operates. There is no apparent reason to believe that a poor performing line will contain hereditary material which will interact more favorably than will a high performing line from the same genetic source.

Winters (1948) has pointed out that high performing individuals are the result of highly effective combinations of genes. Mather and Harrison (1949) and Rempel (1952) set forth the concept that selection is effective for combinations of genes as well as for individual genes. Since inbreeding results in increased homozygosity, it insures the increased frequency of transmission of established combinations of genes from one generation to the next, once a relatively high degree of homozygosity has been achieved. Therefore it is in accord with genetic

reasoning that the highest performing inbred lines should produce the highest performing crosses.

The findings set forth in table 3 are of high importance to both the builders of inbred lines and to those who use them in crossing for commercial production. All reasonable efforts should be made to provide the commercial producer with high performing lines from which to build his crossbreeding program; it behooves the commercial producer to expend considerable effort to ascertain not only the background of breeding of the lines he uses but also to determine the performance pedigree of these lines.

Summary

The performance of 2332 crossbred pigs has been compared to the average of the respective parental lines. The lines involved were developed by flexible systems of inbreeding and selection with selection based on performance. A close agreement was found between genetic diversity and the amount of heterosis expressed. Genetic diversity was found to be as important in continuous crosses as in single crosses; full utilization of the heterotic stimulus requires the use of crossbred females in a continuous crossing program. Rotation crosses were found to be superior to crisscross crosses of equivalent genetic width.

Crosses were found to be less variable in performance than inbred parental lines. Factors contributing to this condition were enumerated. The concept was set forth that lines of divergent background developed under intense selection for the same characters of economic importance will fix different alleles of relatively high production potential; when the lines are then crossed the alleles may produce various genotypes which lead to high performance because, relatively speaking only the alleles of high production potential of the multiple allelic series have been retained in the inbred lines so developed.

Preweaning characteristics exhibited greater heterosis than postweaning characters with a distinct effect on prenatal survival being evident. In general these results illustrate the opposite effects of inbreeding and crossbreeding and support the concept that the effects of inbreeding are progressively more severe as the stage of determination is moved toward the beginning of embryonic life.

The relationship of the performance of inbred lines *per se* to the performance of their crosses was determined by holding genetic diversity constant and comparing each line and each line cross to an

impartial standard. This analysis revealed that the better performing lines produce the better performing crosses. These results are in agreement with genetic expectations; they indicate that the more effective gene combinations in the respective lines also contribute the more effective gene combinations in line crosses. These findings strengthen the case for performance testing as the basis for selection.

The results of this study suggest three genetic essentials for obtaining maximum heterosis in swine crosses: (1) full utilization of genetic diversity, (2) the use of stock from high performing lines, (3) the use of stock from lines that have been sufficiently purged and purified to insure the regular transmission of effective gene combinations from one generation to another.

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TIME OF FARROW AND PERFORMANCE IN SPRING FARROWED PIGS [1]

G. E. Bradford, A. B. Chapman and R. H. Grummer

University of Wisconsin

THE swine industry would be benefited by having a more constant supply of hogs reach market throughout the year instead of the present heavy supply during the late fall months and comparatively light marketings at other times. The principal reason for the existing situation is that the greatest number of pigs are farrowed in March and April, a practice favored by producers to avoid extremes in temperature at farrowing time and to permit maximum use of pasture. The sharp decline in hog prices when the pigs reach market in large numbers has apparently effected little change in the time of farrowing. Knowledge of the comparative performance of pigs farrowed at different times during the spring is of interest because of this heavy spring farrow and because of its possible bearing on the problem of seasonal concentration of market supply.

Methods and Data

Records of gilt litters farrowed and raised on Wisconsin farms in the springs of 1947 to 1950 inclusive were collected through the Wisconsin Swine Selection Cooperative and were studied in an attempt to obtain information on this point. The frequency distribution of the farrowing dates of the litters used in the survey, classified by years and grouped into ten-day periods, is given in table 1.

Two studies were made of the data. The first was a survey of the effect of time of farrowing irrespective of herd. In the second, differences due to relative date of farrowing within herds were analyzed. Characters studied were: (1) number farrowed, (2) number raised to five months, (3) litter weight at five months,[2] (4) sow productivity,[3]

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[2] Divided by 50 for card punching.

[3] In 1947 and 1948, sow productivity was calculated as $N_F + 2N_W + \frac{\text{Weaning Weight of Litter}}{15}$. In 1949 and 1950, no weaning weights were taken and sow productivity was then computed as $N_F + 2N_{154} + \frac{\text{154-day Weight of Litter}}{100}$. Ten points were added for gilt litters in both cases. These two estimates of sow productivity give approximately the same results.

(5) average index,[4] (6) pig weight at five months,[5] (7) percent viability to five months.[6]

General Influence of Spring Farrowing Date on Performance Characters

Records of 20,956 five-month old pigs, raised from 27,289 pigs farrowed in 3134 litters, were used in this study. The data for each

TABLE 1. FREQUENCY DISTRIBUTION OF FARROWING DATES OF GILT LITTERS FROM 445 WISCONSIN FARMS, CLASSIFIED BY YEARS

Date	Year				All Years
	1947	1948	1949	1950	
Jan. 10–Jan. 19	..	2	..	4	6
Jan. 20–Jan. 29	..	..	3	7	10
Jan. 30–Feb. 8	1	3	20	6	30
Feb. 9–Feb. 18	15	16	36	33	100
Feb. 19–Feb. 28	53	47	97	71	268
[1]Mar. 1–Mar. 10	115	87	182	136	520
Mar. 11–Mar. 20	100	143	173	181	597
Mar. 21–Mar. 30	92	79	170	150	491
Mar. 31–Apr. 9	82	70	129	153	434
Apr. 10–Apr. 19	53	60	70	69	252
Apr. 20–Apr. 29	33	52	47	56	188
Apr. 30–May 9	8	28	23	55	114
May 10–May 19	9	8	14	26	57
May 20–May 29	6	17	5	13	41
May 30–June 8	4	9	1	5	19
After June 8	..	6	..	1	7
Total	571	627	970	966	3134

[1] Subtract one day from each date starting March 1 for leap year (1948).

year were classified by breed of gilt, and within each breed of gilt into straightbred and crossbred pigs if the breed of boar was known. This classification was made to find out if there was a disproportionate percentage of pigs of one breed or one type of breeding in any period and thereby avoid confusing the effect of season with the effect of these other factors. The litters within each breed classification were then grouped into early, middle, and late periods with equal

[4] Individual pig index= S.P.+.7 (Weight at 154 Days—74).

[5] Adjusted to 154-day equivalent when pigs were not weighed at exactly 154 days. The weight of one pig, chosen at random, per litter was used in studying this character.

[6] Not calculated for each litter, but computed from the totals for numbers farrowed and raised for each group.

numbers of litters in each. The sum and mean for each period were obtained for each of the seven characteristics.

Mean farrowing dates for the litters in each breed were obtained for each year, and since they were quite consistent from year to year, mean dates were obtained for the four-year pooled data. These mean dates for each breed and also the range of farrowing dates of litters within each breed were sufficiently similar from breed to breed that it was not considered necessary to keep the breeds separate in studying the association of performance with time of farrow. Therefore, only the pooled data for all breeds are presented (table 2).

No consistent trends in the means of the characters classified by time of farrow are shown in the data in table 2. The differences are small and tend to cancel out over the several years. Since the classification of the data ignored herd differences which are known to be large, it was felt that statistical analysis of the data so classified was not desirable.

Influence of Farrowing Date within Herds

The second part of the survey involved the 138 herds[7] which had at least six litters and a standard deviation of farrowing date of at least six days. These conditions were imposed so that the herds, which were divided into early, middle and late thirds, would have at least two litters in each third, with a range in farrowing dates large enough to give some opportunity for detection of any differences in pig performance associated with time of farrow within herds. Choosing only herds with a standard deviation of at least six days eliminated 88 of 226 herds with at least six litters. The remaining 138 herds contained 1497 litters and had an average intra-herd standard deviation of 12.1 days and a range from 6.0 to 33.5 days. The mean farrowing dates of these herds were distributed as follows: January, 1 herd; February, 10; March, 87; April, 33; May, 6, and June, 1.

The litters within each of the herds were divided into three periods with as nearly one-third of the litters in each period as possible. The figures for all early, all middle, and all late periods were then pooled. All of the data for each character except viability were analyzed for each year by analysis of variance, and then the pooled data were analyzed for year and over-all period effects. The variation in the intra-year analysis was divided into between period, between herd,

[7] These are actually herd-years, since some herds were represented in more than one year's data. There were 105 different herds.

TABLE 2. MEAN VALUES FOR PERFORMANCE CHARACTERS OF PIGS FARROWED AT DIFFERENT TIMES DURING THE SPRING FARROWING SEASON

Year	Period	Number of Litters	Mean Farrowing Date [1]	Number Farrowed	Number Raised to 154 Days	Percent Viability to 154 Days	Litter Weight at 154 Days (÷50)	Sow Productivity	Average Index	Pig Weight at 154 Days
1947	Early	189	63.3	8.7	6.3	72.2	16.4	44.2	83.9	129.5
	Middle	193	80.5	8.4	6.2	73.2	16.1	43.3	84.0	132.7
	Late	189	101.9	8.7	6.4	74.1	17.1	44.5	86.2	128.7
	All	571	81.9	8.6	6.3	73.2	16.5	44.0	84.7	130.3
1948	Early	207	64.7	8.0	5.7	70.6	14.5	41.3	78.9	125.6
	Middle	213	85.1	8.6	6.6	76.7	17.8	46.3	89.5	132.7
	Late	207	111.2	8.8	6.8	77.3	19.3	46.7	94.2	140.4
	All	627	87.0	8.5	6.4	74.9	17.2	44.8	87.5	132.9
1949	Early	324	57.7	8.8	6.6	74.8	18.6	41.8	88.7	140.8
	Middle	322	78.8	8.8	6.8	77.0	18.3	42.1	85.8	134.1
	Late	324	101.6	8.9	6.9	77.1	19.1	42.8	88.8	138.6
	All	970	79.4	8.8	6.7	76.3	18.7	42.2	87.8	137.8
1950	Early	323	62.7	8.9	6.8	76.9	18.2	41.8	84.1	132.6
	Middle	320	82.5	8.8	6.5	74.7	17.5	40.9	83.1	133.4
	Late	323	109.7	8.7	6.7	77.1	18.0	41.6	83.9	133.2
	All	966	85.0	8.8	6.7	76.2	17.9	41.4	83.7	133.0
All Years	Early	1043	61.7	8.7	6.4	74.2	17.3	42.1	84.5	133.1
	Middle	1048	81.5	8.7	6.6	75.6	17.5	42.8	85.4	133.3
	Late	1043	106.1	8.8	6.7	76.6	18.4	43.5	87.9	135.5
	All	3134	83.1	8.7	6.6	75.6	17.8	42.8	85.9	134.0

[1] Days from January 1.

period×herd interaction and within herd components. The interaction mean square, where significant, was used as the error term for period and herd mean squares. In the pooled data analysis, in which differences between years and between periods over-all were tested for significance, the year×period interaction mean square was used as the error term if significant. Otherwise, the mean square within periods, herds, and years was used.

The averages obtained in the within herd study are given in table 3. There were a few scattered significant differences between periods in these data, but not for any one characteristic for all years and none for the four-year data pooled. Interaction between periods and herds was almost nonexistent. Differences between herds were highly significant in all characteristics in each year.

The mean squares, and their significance, for years and periods and interaction between these two factors, are given for the pooled data in table 4. Number farrowed, litter weight, and pig weight showed significant differences between years, and there was an interaction between year and period for number of pigs at five months, litter weight at five months, sow productivity and pig index. None of the between period mean squares approached significance, either when the interaction mean square, or the smaller within periods, herds and years mean square, was used as the error term.

It will be noted that the general level of performance of the herds represented in table 3 was lower than for those in table 2. Table 3 is based on records of larger herds only, whereas table 2 is based on records of all herds, including those in table 3. It is therefore apparent that the larger herds involved in this study had a lower average performance than did the smaller ones.

Discussion

No marked differences were found between the different periods for size of litter farrowed or for viability in either part of this study. The maximum difference between periods in number farrowed in any one year was 0.8 pig for the first part of the study, and 0.7 pig for the second part, and for the pooled data this difference was only 0.1 pig for each study. Differences in mortality were less than 2.5 percent from the lowest to the highest group for the pooled data of each study. This is in contrast to the frequently expressed view that early farrowed pigs suffer much higher mortality than do those farrowed later.

TABLE 3. AVERAGES OF PERFORMANCE CHARACTERS FOR LITTERS FARROWED AT DIFFERENT PERIODS WITHIN HERDS IN THE SPRING FARROWING SEASON

Year	Period	Number of Litters	Number Farrowed	Number Raised to 154 Days	Percent Viability to 154 Days	Litter Weight at 154 Days (÷50)	Sow Productivity	Average Index	Pig Weight at 154 Days
1947	Early	82	8.7	6.4	72.8	15.8	44.5	79.6	123.3
	Middle	81	8.1	5.6	68.8	14.0	41.3	76.7	122.2
	Late	82	8.3	5.6	67.5	14.2	41.7	78.7	125.6
	All	245	8.4	5.9	69.8	14.7	42.5	78.4	123.7
1948	Early	90	7.9	5.4	68.8	13.7	41.0	78.4	126.7
	Middle	90	8.6	6.1	70.5	15.7	43.5	81.4	126.0
	Late	90	8.6	6.5	75.4	16.3	44.7	83.1	124.8
	All	270	8.4	6.0	71.7	15.2	43.1	81.0	125.8
1949	Early	146	8.7	6.4	73.8	17.8	40.9	85.9	135.9
	Middle	159	8.8	6.7	75.9	18.5	42.0	86.4	138.4
	Late	146	8.7	6.4	73.8	16.8	40.6	81.8	132.0
	All	451	8.7	6.5	74.6	17.7	41.2	84.7	135.3
1950	Early	179	8.6	6.6	76.1	17.4	40.8	82.8	132.2
	Middle	173	8.7	6.8	78.3	17.8	41.6	81.5	129.8
	Late	179	8.8	6.6	75.8	17.3	41.0	81.2	128.2
	All	531	8.7	6.7	76.7	17.5	41.1	81.8	130.1
All Years	Early	497	8.5	6.3	73.6	16.6	41.5	82.4	130.6
	Middle	503	8.6	6.5	74.7	17.0	42.0	82.3	130.6
	Late	497	8.6	6.4	73.8	16.5	41.7	81.3	128.3
	All	1497	8.6	6.4	74.1	16.7	41.7	82.0	129.8

The small and variable differences found between the means for the different periods do not indicate that any particular time during the spring farrowing season is superior for performance of swine in the characters studied. This was, however, not an experiment, but a survey of the net effect of all the factors influencing pig performance under farm conditions. Some of these factors may be controllable, others not; the extent to which their control may effect the results is of course not determinable from a study of this kind. Some factors may be exerting a positive effect and others a cancelling negative effect on the characters studied. For example, younger sexual age of

TABLE 4. MEAN SQUARES FROM ANALYSIS OF VARIANCE OF YEARS AND PERIODS

Source of variation	Degrees of Freedom	Mean Squares					
		Number Farrowed	Number at 154 Days	Litter Weight at 154 Days (÷50)	Sow Productivity	Average Pig Index	Pig Weight at 154 Days
Between years	3	12.3*	53.3	783.3	316.0	2319.3	8964.0**
Between periods	2	2.0	3.0	40.0	37.0	180.0	926.5
Interaction Year x period	6	7.3	14.5**	103.5**	218.7**	527.0*	575.8
Within periods, herds and years	1083	4.1	4.0	30.6	68.1	201.5	656.9

*P<.05.
**P<.01.

some of the gilts which farrow early may tend to reduce the litter size of the early farrowing group (Warnick *et al.*, 1951; Robertson *et al.*, 1951) whereas some of the late farrowing group may be late because of reproductive abnormalities which reduce litter size as well as delay conception. Factors such as disease and cold weather both cause mortality of young pigs, but each may exert its greatest influence at a different time during the season.

Other factors may change from one time to another during the farrowing season in the relative importance of their effects on pig performance, with the combined effects of all such factors resulting in the different periods being similar. This survey, based on the records of a large number of litters from several hundred farms over a four-year period, does not provide information as to what intermediate factors may be acting, but it does indicate that the net influence of all seasonal factors is very small, and not predictable from year to year. No information on the management practiced in

these herds or on the profitability of production of these pigs was available, and hence no recommendations as to the optimum time of farrowing, from the standpoint of net returns from the swine enterprise, can be made as a result of this study. There is an important need for experimental work on the effect of season of farrowing, in which at least some of the factors causing variability in performance can be controlled, and in which the relation of income to costs can be studied for the different periods.

Summary

The association of time of farrow and pig performance is of interest to both hog producers and packing companies. An analysis of records from 445 Wisconsin farms for the years 1947 to 1950 provides information on this problem in spring farrowed litters.

The differences in performance of pigs farrowed in the early, middle, and late spring groups, with regard to such characters as litter size, viability, and weight for age, were found to be small and not consistent from year to year. Such differences as were found tended to cancel over all years. The same general conclusions held whether the data were classified grossly or on an intra-herd basis. The need for controlled experimentation on this phase of swine production and for data on the ratio of income to cost was stressed.

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THE RELATIONSHIP BETWEEN LIVE HOG SCORES AND CARCASS MEASUREMENTS [1]

L. J. Bratzler and E. P. Margerum, Jr.[2]

Michigan Agricultural Experiment Station [3]

THE marketing of slaughter hogs has received considerable attention in recent years. The gradual decline in the value of lard in relation to the balance of the pork carcass has emphasized the desirability of a hog that will produce a larger percentage of the high value or preferred cuts (skinned hams, loins, bellies, Boston butts and picnic shoulders). Under the present marketing system, it is essential that the producer or his selling agent possess the ability to determine accurately the proportion of preferred cuts that any hog or group of hogs will produce.

Objective carcass standards (1952a) have been proposed and adopted that predict with some accuracy the amount of high value cuts that can be realized. These grades (Choice #1, #2, #3, Medium and Cull) are based on the average backfat thickness and weight or length of carcass. An attempt has been made to refer these standards back to the live hog in order to produce a usable live grading system (1952b). Weight, body length, thickness of backfat and dressing percentage are the major factors that determine the yield of preferred cuts from the live animal.

In a cooperative study [4] to determine factors influencing the marketing of meat type hogs, it was possible to have three men score hogs prior to slaughter and processing. It was thought desirable to obtain information relative to the reliability of live hog estimation in regard to body length, finish as measured by backfat thickness, and percentage of preferred cut yield.

Methods

The hogs used were representative of those on the Detroit market and were produced on Michigan and Ohio farms. A total of 434 hogs were scored by three judges who were experienced livestock men, including one packer buyer. Only one of the judges had the opportunity to view the carcasses prior to cutting. The hogs were weighed individually, identified by tattoo number and then scored by the

[1] Journal Article 1534 Michigan Agricultural Experiment Station.
[2] Present address, University of Wyoming, Laramie, Wyoming.
[3] Department of Animal Husbandry.
[4] Farm Credit Administration, U.S.D.A., Bureau of Animal Industry, U.S.D.A., Detroit Packing Co., Ohio Agricultural Experiment Station, and Michigan Agricultural Experiment Station Cooperating.

judges. Three weight groups of hogs were used, 181–200 lbs.; 201–220 lbs.; 221–240 lbs. and represented 23 breed and crossbred classifications.

The judges scored each hog for length and for finish on the basis of numbers ranging from 1 to 5. A score of 3 was considered average for the weight group with number 1 characteristic of shortness and lack of finish. Number 5 was used to indicate hogs that were very long and also hogs considered to be overfinished for the weight classification. Estimations of the preferred cut yield, live weight basis, were made to one-half percent, without establishing any minimum or maximum limits. After scoring, the hogs were slaughtered, the

TABLE 1. DISTRIBUTION OF HOGS BY WEIGHT GROUPS AND RANGE IN ACTUAL MEASUREMENTS

Weight Group	Number of Hogs	Actual Range Length mm.	Actual Range Backfat mm.	Actual Range Cutout %
181–200 lbs.	110	691–809	22–50	43.8–52.7
201–220 lbs.	265	691–830	23–61	42.4–51.9
221–240 lbs.	59	725–861	29–58	43.3–51.7

carcasses chilled for 24 hours and then weighed and measured. The carcasses were cut 48 hours after slaughter.

Carcass length was measured from the anterior edge of the aitch bone to the anterior edge of the first rib. Backfat thickness was measured over the seventh rib. All measurements were recorded in millimeters. After cutting, the bellies, loins, skinned hams, Boston butts and picnic shoulders were weighed to the one-tenth pound.

Results and Discussion

The distribution of hog numbers by weight group and range in actual measurements are presented in table 1. The study was originally designed to include only 201–220 lb. hogs, and the two additional weight classifications were added to secure sufficient hog numbers for a more economical cutting schedule.

The judges were least accurate in estimating the percentage of preferred cuts (liveweight basis) when the coefficients of correlation are considered as given in table 2. In addition to fatness, length and other characteristics, dressing percent, or carcass yield, has an important influence on the preferred cut-out of any hog under consideration. Weights of stomach and viscera, including contents, were

not taken, so it was impossible to adjust live slaughter weights to a uniform "fill."

Even though many of the r values are highly significant, the amount of unexplained variation ($1-r^2$) is large. The judges felt that the weight group ranges used were too narrow for the most accurate estimation of the various factors. The live hogs were not segregated by weight groups for scoring and differences between hogs of different weights were difficult to estimate.

TABLE 2. RELATIONSHIP BETWEEN JUDGES ESTIMATES OF BODY LENGTH BACK FAT AND PREFERRED CUT YIELD AND THE ACTUAL RESPECTIVE MEASUREMENTS

	Coefficients of Correlation								
	181–200 lb.			201–220 lb.			221–240 lb.		
Item	Judge A	Judge B	Judge C	Judge A	Judge B	Judge C	Judge A	Judge B	Judge C
Body length	.66**	.57**	.60**	.39**	.42**	.29**	.18	.15	.13
Back fat thickness	.47**	.48**	.52**	.42**	.42**	.50**	.21	.29*	.38**
Preferred cut yield	.22*	.30**	.28**	−.08	.22**	.13	.10	.34**	.35**
r=5%		.20			.14			.25	
r=1%		.25			.18			.33	

* Significant at 5% level.
** Significant at 1% level.

Although there were only 59 hogs scored from the 221–240 lb. group, the judges' estimations of all characteristics were least accurate for these hogs. Most accuracy was achieved in the estimation of body length and back fat thickness of hogs in the two lighter weight groupings.

Summary

Three experienced livestock men scored 434 hogs for body length, back fat thickness and preferred cut yield. Estimation of preferred cut yield was most difficult, while a closer relationship between live scores for finish and length and carcass measurements was obtained with lighter weight hogs.

It would appear that considerable training and experience is necessary to accurately grade live hogs of all weights into the present grades of Choice #1, #2, #3, Medium and Cull.

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A FURTHER INVESTIGATION OF SPECIFIC GRAVITY AS A MEASURE OF PORK CARCASS VALUE

JOE V. WHITEMAN, J. A. WHATLEY and J. C. HILLIER

Oklahoma Agricultural Experiment Station [1]

THERE is an ever-present need for better measures of characteristics of economic importance in animal breeding investigations. This need becomes even more important when such a characteristic as carcass muscling or leanness is considered because until recently (Hazel *et al.*, 1952) it was difficult to get a very accurate appraisal of carcass merit on a live hog. Consequently, it was necessary to use a sib or progeny test to get a measure of a breeding animal's worth with respect to carcass merit.

Brown and others (1951) suggested that the specific gravity of the carcass was more highly associated with carcass fatness than was average back fat thickness—the standard measure of this characteristic. The investigation reported here was an attempt to further evaluate specific gravity as a measure of pork carcass merit and to study some possible sources of error in its use.

Materials and Methods

There were 332 carcasses used in this study; 249 were from pigs from the Swine Breeding Project conducted by the Oklahoma Experiment Station in cooperation with the Regional Swine Breeding Laboratory. These included 52 carcasses from eight Duroc inbred lines; 96 carcasses from single- and multiple-line crosses of Duroc lines; 12 carcasses from outbred Durocs; 67 carcasses from crosses of Durocs and Minnesota No. 1, Minnesota No. 2, Poland-China, and Landrace-Poland; and 22 carcasses from Landrace-Poland pigs. There were 63 top cross and line cross Duroc carcasses from individual feeding experiments. The other 20 carcasses were from Chester White, Poland-China, Hampshire, and Berkshire pigs from the Animal Husbandry swine herd.

The manner in which these carcasses were used in the study will be indicated in more detail where appropriate. The management of the pigs prior to slaughter, the killing methods, and the measuring

[1] Animal Husbandry Department in cooperation with the Regional Swine Breeding Laboratory (Ames, Iowa), Bureau of Animal Industry, Agricultural Research Administration, U.S.D.A.

and cutting techniques were the same as those given by Whiteman and others (1951) unless otherwise indicated.

To obtain the specific gravity value it was necessary to get the air and water weight of the carcass. The air weight was recorded to the nearest one-tenth of a pound on the platform scales shown in figure 1. The half carcass was then completely immersed in water in the tank under the balance scales. It was suspended by a hook on the end of the string shown tied to the arm of the scales. This weight was read to the nearest .01 pound. The air and water weights of the two half carcasses of each hog were added and the sums used in the following formula to get the carcass specific gravity.

$$\text{Specific gravity (Sg)} = \frac{\text{Air weight}}{\text{Air weight minus water weight}}$$

Specific gravities are coded as follows:

$$(\text{Sg} - 1.0)\,1000 = \text{Coded value. Ex. } (1.054 - 1.0)\,1000 = 54$$

Experimental Procedure

The right hams of 23 carcasses were used to determine the sensitivity of the specific gravity values to variations in the amount of water, protein and ether extract in the lean portion of the ham. These carcasses were from barrows and gilts varying in weight from 182 to 250 pounds. Except for four which were from a Duroc inbred line, they were from Landrace-Poland×Duroc crossbred pigs. Thus representing a rather variable group of carcasses.

The weight, average back fat thickness, and specific gravity were obtained from the right half of each carcass after they were thoroughly chilled. The ham was removed from each half carcass, tagged and placed in the cooler until the following week. At that time the specific gravity was determined on each ham. The hams were then separated into external fat and skin, lean and bone. The specific gravity and percentage of total untrimmed ham was then measured and calculated on each of these three principal tissues of the ham.

The muscles of the hams were tagged and chilled again for about 24 hours. They were then run through a coarse grinder twice. After the second grinding two large samples were taken from each ham muscle. These in turn were run through a fine grinder twice and a three- to four-ounce sample taken for chemical analysis. The samples were sealed in jars, quick frozen, and held until the analyses were run. Dr. V. G. Heller, Department of Agricultural Chemistry, made

determinations for percentages of moisture, protein and ether extract on each of two samples which he took from each ham sample. The average of the four sets of determinations on each ham was used in the subsequent calculations.

Results

The multiple regression technique (Snedecor, 1948) was used to determine the dependency of the obtained specific gravity of the lean of the ham on the percentages of moisture, protein and ether extract. Following are the simple correlations between specific gravity and the percentages of moisture (M), protein (P), and ether extract (EE) in the lean of the ham and also the standard partial regression coefficients between the same variables:

	M	P	EE
Correlation with Sg	.832	.820	−.868
Standard regression of Sg on	.622	.508	.118

The multiple correlation coefficient was .912, indicating that about 83 percent of the variance of specific gravity was dependent upon the percentages of moisture, protein and ether extract. The multiple regression equation was as follows:

$$\text{Est. Sg} = 1.54\,M + 3.61\,P + .23\,EE - 125$$

The standard error of the estimated coded specific gravities was 2.50.

There were at least four sources of variation which might account for some of the 17 percent of the variance of specific gravity that was not related to variations in the percentages of moisture, protein and ether extract:

1. The scales which were used to obtain the specific gravity weights may not have weighed with sufficient accuracy and there are always errors due to rounding off.

2. The ash content of the lean meat was not determined, so that this variable was not accounted for in-so-far as it was independent of the percentages of moisture, protein and ether extract.

3. It is known that the temperature of meat affects its density. There were very likely temperature variations among the pieces of lean meat at the time that they were water weighed.

4. Any errors that were due to the sampling of the hams preparatory to the chemical determinations would partially account for otherwise unaccountable variation in the specific gravity values obtained. Brown and others (1951) suspected their sampling technique to be an

important source of error. The values for percentages of moisture, protein and ether extract that were used in calculating the multiple correlation coefficient were means and were therefore subject to sampling error.

In order to get an estimate of the extent of this sampling error, two samples were taken from each ham muscle as previously described and two determinations were made on most of these samples. Analysis

TABLE 1. MEAN SQUARES, COMPONENTS OF VARIANCE AND PERCENTAGES OF TOTAL VARIATION CONTRIBUTED BY EACH COMPONENT FOR PERCENTAGES OF MOISTURE, PROTEIN AND ETHER EXTRACT IN THE HAM SAMPLES

Portion of Lean	Source of Variation	Degrees of Freedom	Mean Square	Component	Est. of Relative Importance
Moisture	Between hams	22	26.25	6.571	88.2
	Between samples	23	1.41	.598	8.0
	Within samples	41	.279	.279	3.8
Total				7.448	
Protein	Between hams	22	3.12	7.082	97.8
	Between samples	23	.29	.130	1.8
	Within samples	46	.028	.028	.4
Total				7.240	
Ether extract	Between hams	22	40.93	10.249	35.4
	Between samples	22	3.01	1.358	11.3
	Within samples	40	.390	.390	3.3
Total				11.997	

of variance (table 1) showed that in every case the differences between muscle samples were highly significant. The mean squares were reduced to theoretical components of variance (Rigney and Blaser, 1948). The estimate of relative importance is the percentage of the total variation of each lean constituent that was due to each source of variation.

From table 1 it can be noted that 8 percent of the total variation of percentage moisture and 11.3 percent of the variation of percentage ether extract were due to the sampling of the lean. Sampling, then, appears to be an important source of variation. The means of these samples also varied; and, in-so-far as the sampling errors were random

in nature, the relationship $\delta\frac{2}{x} = \frac{\delta^2}{n}$ indicates the extent that sampling errors affected the mean values that were used in the multiple regression equation. Therefore, part of the failure of the multiple correlation coefficient to be unity was due to the failure of the values used in the multiple regression equation to be the true values of the percentages of moisture, protein and ether extract.

The seventeen percent of the variance of specific gravity unaccounted for by the multiple correlation coefficient may be largely included in the sources of error that have been discussed. Certainly some of it is distributed among these sources. Since all these forces—and perhaps others—were acting to prevent the unity correlation, it would seem that specific gravity may have been reflecting the differential proportions of moisture, protein and ether extract very accurately.

The Relationships among the Proportions of Fat, Lean and Bone

The data on these hams were studied further to get estimates of some of the relationships that exist among the proportions and densities of the three principal tissues of the ham, i.e., fat (including skin), lean and bone. Physical separation of the fat and skin cannot be done accurately and therefore was not attempted. Consequently, no accurate information was gathered regarding their densities or proportions. It is known, however, that the density of the skin is greater than that of the fat. It seems reasonable, also, that the skin is less variable in amount than is the fat. If each is constant in density, then those pieces which contain the least fat will have the highest proportion of skin and will have higher specific gravities. It is believed that this accounts for much of the variation in the densities found among the fat and skin pieces. Their associations with the other parts of the ham support this hypothesis. Table 2 shows some of the simple correlations among the percentages and densities of the principal tissues of the hams.

Perhaps the most striking value in table 2 is the correlation coefficient of .949 between the specific gravities of the ham and of the half carcass. This value was so high that it was decided to repeat this portion of the study to see if this estimate could be repeated with carcasses from hogs treated the same before slaughter and killed at a constant weight. This was done using 46 carcasses from pigs of Duroc, Landrace-Poland, and Duroc×Landrace-Poland breeding. The correlation coefficient was .942 and when put on an intra-breed

basis was .894. This suggests two conclusions. First. it supports the findings of other workers (Aunan, 1951; Hankins *et al.*, 1934; Hetzer *et al.*, 1950; and McMeekan, 1941) that the proportions of the various tissues of the ham are indicative of the proportions of the respective tissues in the entire carcass. Second, specific gravity was measuring the proportions of the various tissues very accurately or such high degree of associations would not have been found.

It will also be noted that the specific gravity of the ham was positively and significantly correlated with the specific gravities of

TABLE 2. CORRELATIONS AMONG THE PERCENTAGES AND SPECIFIC GRAVITIES (Sg) OF THE PARTS OF THE HAM

Variable	Sg (Half Carcass)	Sg (Ham)	Sg (Fat and Skin)	Sg Lean	Sg Bone	% Lean
Sg (ham)	.949	....	....	....	....	....
Sg (fat and skin)	.654	.611	....	....	....	....
Sg (lean)	.767	.779	.578	....	....	....
Sg (bone)	.554	.567	.220	.625	....	....
% lean	.761	.778	....	.521	....	....
% bone	.413	.468	....	....	—.181	.302
% fat and skin	—.828	—.849	—.630	—.558	—.253	—.948

$r = .413 = P_{.05}$ of chance occurrence.

the three parts of the ham and with the percentages of lean and bone. There seems little doubt that associations between the specific gravities of the parts of the ham and that of the whole ham exist. However, since the correlations are between measurements on a part and the whole, the magnitude of the associations as they were measured may be questioned. There seem to be no grounds for doubting the correlations between the specific gravity of the ham and the percentages of the three tissues of the ham.

Another value from table 2 was very interesting. The correlation estimate of —0.181 between percentage and density of bone may be of considerable significance. Bone has the greatest density of any tissue in the carcass. If the variation in amount or density of bone were sufficient to have a major effect on the carcass specific gravity, selection for carcass specific gravity in a breeding program would result in considerable selection pressure on the amount or density of bone. If percent and density of bone were strongly and positively correlated, this tendency would be increased.

In these data at least, both percentage lean and percentage fat were much more closely associated with specific gravity than was percentage bone. In fact, about 78 percent ($1-r^2$) of the variance of specific gravity was independent of percentage bone. On the other hand, only about 28 and 39 percent of the ham specific gravity variance was independent of percentage fat and skin and percentage lean, respectively.

There were two other groups of carcasses from which some data could be obtained and studied. In the first of these groups of carcasses (32 Duroc carcasses from another project), percentage bone of the half carcass was correlated with the specific gravity (0.752), and with percentage lean cuts (0.763). Specific gravity was correlated with percentage lean cuts (0.783). When percentage lean cuts was held constant by a partial correlation technique (Snedecor, 1948) the correlation between percentage bone and specific gravity was reduced to 0.384. This suggested that the high association on the simple correlation basis was partially due to their joint correlations with percentage lean cuts.

The other group for study was composed of 31 half carcasses in which the following correlations existed:

Variable	X_2 % Bone	X_3 % Lean Cuts	X_1 Sg (Bone)
X_1 Sg (half carcass)	.681	.904	.261
X_2 % bone	....	.679	.111
X_3 % lean cuts	....	....	.132

$r_{12.3}=0.214$.

Although the correlation between specific gravity of the half carcass and percentage bone was high on a simple correlation basis, again it was materially reduced when percentage lean cuts was held constant by partial correlation. Bone density was not, in this case, significantly correlated with any of the other variables.

Selection for specific gravity would exert considerable selection pressure on percentage bone, but this appears to be largely due to their covariation with lean cuts. The high correlation between specific gravity of the half carcass and percentage lean cuts is very desirable because an increase in lean cuts is what is really wanted in selecting for better carcasses. The amount of selection pressure, independent of percentage lean cuts, that would be exerted on percentage bone

with a selection program based on carcass specific gravity would appear to be slight. This phase of the investigation needs further study.

A Comparison of Specific Gravity and Average Back Fat Thickness as Measures of Carcass Leanness

This part of the study involved the use of 203 carcasses from pigs from the four farrowing seasons of 1949 and 1950. The methods of

TABLE 3. COMPARISONS OF SPECIFIC GRAVITY (Sg) AND AVERAGE BACK FAT THICKNESS (BF) CORRELATIONS WITH OTHER CARCASS MEASURES (INTRA BREED)

Measure	Group	Sg	BF
% lean cuts [1]	A	.868*	—.785
	B	.647	—.590
% ham and loin [1]	A	.888**	—.701
	B	.586	—.457
% ham [1]	A	.806**	—.634
	B	.572	—.527
% loin [1]	A	.789**	—.623
	B	.450	—.311
Ham lean area (LXW)	A	.439	—.267
	B	.374	—.404
Ham lean area (Plan.)	A	.667**	—.438
	B	.402	—.389
Loin lean area (LXW)	A	.602**	—.436
	B	.336	—.264
Loin lean area (Plan.)	A	.689**	—.433
	B	.465	—.289
Specific gravity	A	....	—.746
	B	....	—.482

* Denotes significance at the .05 level.
** Denotes significance at the .01 level.
[1] =Based on chilled carcass weight.
LXW=length times width approximation.
Plan.=a planimeter reading of a tracing of the lean muscle.

slaughtering, chilling, cutting and measuring have been described by Brown *et al.*, 1951, and Whiteman *et al.*, 1951.

Simple correlation coefficients were calculated on an intra-breed basis for each season between all of the carcass measures. Two seasons data were from carcasses in which there were sex differences involved. These were combined using the z transformation (Snedecor, 1948) and are designated as the A group. The B group included barrow carcasses in the other two seasons and was handled in a like manner.

Table 3 shows a summary of these correlation coefficient estimates between specific gravity and the other measures of carcass leanness and also between average back fat thickness and the other measures. Hotelling's (1940) test of significance was used to determine the probability that specific gravity was more highly correlated with the other measures than was average back fat thickness. The sign of the correlation coefficient was ignored.

It will be noted that significance was found in every comparison which involved the A group of carcasses. Associations were generally lower with the B group of carcasses than with the A group. The difference between the A and B group correlation coefficients was always greater when the measure was correlated with specific gravity than when the same measure was correlated with average back fat thickness. One of the two seasons' data that went into the B group correlation coefficients was gathered the first season that the senior author was present and it is thought that cutting errors may have accounted for much of the variation obtained in that season. The water weights for the specific gravity values were obtained with an old gram balance scale that may have been misread. Such errors, if random, would tend to reduce the size of the correlation coefficients.

The A group carcasses indicate rather conclusively that average back fat thickness was not as closely associated with these measures of carcass leanness as was specific gravity.

Considerations in the Use of Specific Gravity

Several years of experience in the use of the specific gravity technique has produced the following bits of information of value to those interested in water-weighing carcasses:

1. Water temperature variations if within a 20° F. range are of no practical consequence.

2. The weight must be read quickly or the warming effect of the water will reduce the carcass weight in water. This is related to the fact that the specific gravity or relative density of a carcass becomes less as its temperature increases. A fresh-dressed, warm carcass will float.

3. Differences in the amount of exposed surface on different carcasses appear to be of no practical consequence.

4. Differences in water purity from day to day may be important if they affect changes in the density of the water.

5. The longer the carcass is left in the water the less its density (up to three hours) and therefore a second reading taken a few minutes after the first is less than the first.

6. When weighing half carcasses, the weight in water is sufficiently accurate if weighed to the nearest .01 of a pound. Smaller pieces of meat should be weighed more accurately.

Summary

A multiple correlation coefficient of .912 was found between the specific gravity of the lean of 23 hams and the percentages of moisture, protein and ether extract. It was found that the sampling of the meat may be an important source of error when chemical analysis is used to evaluate carcasses. Correlation coefficients of .949 and .942 were obtained between the specific gravities of the right hams and the half carcasses from which they came, using two groups of 23 and 46 carcasses respectively.

A study of the associations of the parts of the ham with specific gravity indicated that the percentages of either the fat and skin or lean have a greater influence on the specific gravity of the ham than does the percentage of the bone. The densities of the fat and skin and the lean also were more closely associated with the ham density than was the density of the bone.

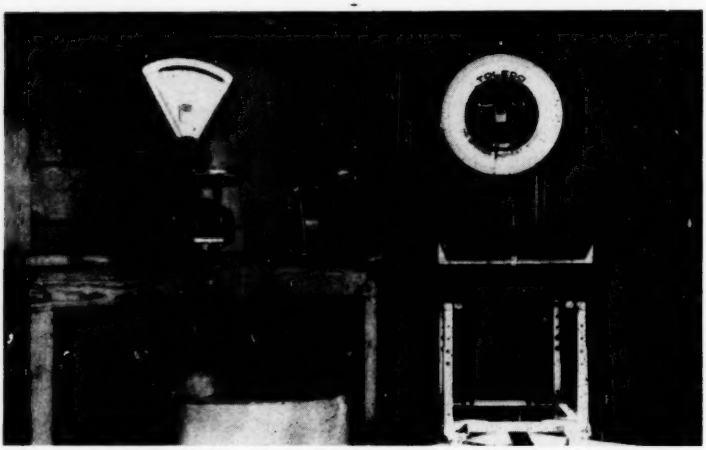

Figure 1. Equipment used to obtain weights for specific gravity calculation.

Simple intra-breed correlation coefficients were calculated for each of eight measures of carcass leanness with specific gravity and average back fat thickness, using data from 203 carcasses. In one group of data, specific gravity was significantly more highly correlated with other measures of carcass leanness than was average back fat thickness. In the other group of data specific gravity was also more highly associated (though not significantly) with other measures of carcass leanness than was average back fat thickness.

A discussion of some of the factors that have been or need to be considered in using the specific gravity technique is also included.

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QUANTITATIVE THREONINE REQUIREMENT OF THE WEANLING PIG [1]

W. M. Beeson, H. D. Jackson and E. T. Mertz [2]

Purdue University Agricultural Experiment Station

AMINO acid studies with growing swine carried out at this station and elsewhere during the past several years have shown that the weanling pig requires the same ten essential amino acids that are required by the weanling rat (Mertz *et al.*, 1952). Data on the quantitative amino acid requirements of the weanling pig are incomplete. To date, quantitative requirements based on growth have been reported for tryptophan (Shelton *et al.*, 1951a), lysine (Brinegar *et al.*, 1950a; Shelton *et al.*, 1951b), methionine (Shelton *et al.*, 1951c; Curtin *et al.*, 1952a), and isoleucine (Brinegar *et al.*, 1950b). Following the proposal of Mitchell (1950), Curtin *et al.* (1952b) calculated the quantitative amino acid requirements for the growth of swine from data obtained by the analysis of swine tissues. The estimate for threonine was 2.4 percent of the crude protein. Sewell *et al.* (1952) reported a threonine requirement of 0.9 percent of the diet (3.6 percent of the protein) in growth experiments with the suckling pig. In the growth experiment reported here the quantitative threonine requirement of the weanling pig was found to be 0.4 percent of the diet (3.0 percent of the crude protein). A quantitative threonine requirement based on growth has not been reported previously for the weanling pig.

Previous experiments on quantitation of amino acids in swine have used diets containing proteins or protein hydrolysates deficient in the amino acid under test. In our experiment protein was supplied by corn combined with pure amino acids which provided threonine at various levels. The ten amino acids essential for the rat and pig balanced the corn protein and increased the protein equivalent to an adequate level so that efficient growth was produced with all rations containing sufficient threonine.

[1] Contribution from the Departments of Animal Husbandry and Agricultural Chemistry, Purdue University, Lafayette, Indiana, as Journal Paper No. 695.

[2] The authors are grateful to Dr. J. Waddell, E. I. du Pont de Nemours & Company, Newark, Delaware, for the DL-lysine·HCl and to Dr. W. Colby, Dow Chemical Company, Midland, Michigan, for supplying several amino acids.

Experimental

The basal ration consisted of 88 percent corn and appropriate supplements of purified amino acids, vitamins, minerals, and other nutrients required by the pig (table 1). Rations with higher threonine levels contained DL-threonine in place of part of the diammonium citrate and cerelose. The ration containing the most threonine contained no diammonium citrate and only 0.16 percent cerelose. All rations contained the equivalent of 13.2 percent crude protein (N×6.25). Digesti-

TABLE 1. COMPOSITION OF THE BASAL RATION USED TO DETERMINE THE THREONINE REQUIREMENT OF THE WEANLING PIG

Component	Percent of Ration	Mineral Mixture [4]	Percent
Corn [1]	88.00	KCl	4.86
Nine essential amino acids [2]	6.04	$CaHPO_4$	36.40
Diammonium citrate	0.95	NaCl	16.40
Minerals	4.30	$CaCO_3$	29.10
Liver extract	0.50	$MgCO_3$	10.30
Cerelose	0.21	$Fe_4(P_2O_7)_3 \cdot 9\,H_2O$	2.56
		$CuSO_4$	0.024
		$MnCl_2$	0.024
	100.00 [3]	ZnO	0.019
		$CoCO_3$	0.019
		KI	0.275

[1] Contained 8.2% crude protein and 14.1% moisture by analysis.
[2] For composition see table 2.
[3] Crystalline terramycin·HCl (10 mg./lb. feed) and crystalline B_{12} (10 μg./lb. feed) were added to all rations. Vitamin supplements used previously (Mertz, *et al.* 1952) were fed daily.
[4] Modified for the corn ration from Heinemann *et al.* 1946.

bility of corn protein as used in these experiments, 78 percent, is the average of the swine values given by Schneider (1947). This value was confirmed for the corn of these experiments by digestibility trials with rats.

The amino acid analysis of the corn was carried out with Leuconostoc mesenteroides P-60 by the microbiological method of Steele *et al.* (1949). Nitrogen and moisture were determined by standard methods of A.O.A.C. (1945). Crystalline amino acids used in these studies were commercial products. The levels fed, the form in which they were added, and the total utilizable amino acids present in the rations are summarized in table 2. We have considered that the amount of amino acid which can be utilized is that present in the

digestible protein of the corn plus that amount of crystalline amino acid which is physiologically active for the rat as described by Rose *et al.* (1949); the D-form is not active except in methionine, phenylalanine, and tryptophan.

Fifteen crossbred barrows averaging 24.3 lb. (age 5–6 weeks) were divided into five lots on the basis of starting weight and were housed

TABLE 2. AMINO ACID COMPONENTS OF THE BASAL RATION USED TO DETERMINE THE THREONINE REQUIREMENT OF THE WEANLING PIG

Amino Acid	Amino Acid Value % of Air Dry Corn	Digestible Amino Acid Supplied by Corn [1] % of Ration	Added Crystalline Amino Acid % of Ration	Form of Amino Acid Used	Total Utilizable Amino Acid [2]	
					% of Ration	% of Crude Protein [3]
Arginine	0.17	0.12 [1]	0.10	L·HCl	0.20	1.5
Histidine	0.15	0.10	0.38	L·HCl·H_2O	0.38	2.9
Isoleucine	0.22	0.15	0.70	DL	0.50	3.8
Leucine	0.80	0.55	0.26	L	0.81	6.1
Lysine	0.15	0.10	2.25	DL·HCl	1.00	7.6
Methionine	0.13	0.09	0.51	DL	0.60	4.5
Phenylalanine	0.26	0.18	0.72	DL	0.90	6.8
Threonine	0.29	0.20	0	DL	0.20	1.5 [4]
Tryptophan	....	....	0.20	DL	>0.20	>1.5
Valine	0.35	0.24	0.92	DL	0.70	5.3

[1] Assay value × % corn in diet × % digestibility of corn protein, or assay value × 88% × 78%.
[2] Digestible amino acid from corn plus physiologically active amino acid from the crystalline form.
[3] Crude protein=13.2% of ration.
[4] Threonine level in the basal ration.

in individual concrete pens. They were fed *ad libitum* twice daily. Vitamin supplements were prepared to supply the daily requirement of the individual pig and then carefully mixed with the evening feed. Since the ration contained a high percentage of grain, there was no adjustment period. The experiment was in progress thirty-five days.

Results and Discussion

Rose *et al.* (1949) reported that D-threonine does not affect the growth of rats, and we have assumed that this is also true for young swine. In our discussion only the level of L-threonine will be considered.

Data summarized in table 3 show that the growth rate of the

weanling pig is greatly affected by the level of threonine in the ration. While 0.2 percent L-threonine is inadequate for optimum gain, 0.4 percent L-threonine promotes growth which is equal to or greater than that with higher levels of threonine. During the 35-day experiment the highest rate of gain (0.99 lb./pig/day) was made by pigs receiving 0.4 percent or 0.6 percent L-threonine. Such growth is highly satisfactory for pigs of this size and is equivalent to a gain of 4.0 percent of the starting weight.

TABLE 3. AVERAGE DATA [1] FOR PIGS RECEIVING VARIOUS LEVELS OF THREONINE IN THE DIET

Added DL-threonine	0	0.4%	0.6%	0.8%	1.0%
Total utilizable L-threonine	0.2%	0.4%	0.5%	0.6%	0.7%
Initial weight (lb.)	24.8	24.0	23.8	24.5	24.5
Final weight (lb.)	43.6	58.5	53.1	59.3	56.8
Daily gain (lb.)	0.54	0.99	0.84	0.99	0.92
Daily feed consumption (lb.)	2.08	2.39	2.23	2.68	2.48
Feed per pound of gain (lb.)	3.85	2.41	2.66	2.71	2.70
Protein efficiency [2]	2.0	3.1	2.9	2.8	2.8

[1] Three pigs/lot. Duration of experiment 35 days.
[2] Pounds gain per pound crude protein

In tests run simultaneously with the swine experiments, rats fed the corn-amino acid diets gave the same results as we obtained with the pigs, i.e., optimum growth with 0.4 percent L-threonine. This level is slightly lower than the threonine requirement of the weanling rat (0.5 percent of the diet) reported by Rose *et al.* (1952). Considering the different type of diets involved, this agreement is quite satisfactory.

In the swine studies feed was utilized most efficiently by pigs consuming 0.4 percent L-threonine (table 3). Unfortunately, our studies did not include a 0.3 percent threonine ration. However, since data from this experiment showed that maximum gain and feed utilization were realized for the weanling pig with a diet which contained 0.4 percent L-threonine, this level is tentatively suggested as the requirement. This threonine value is equivalent to 3.0 percent of the crude protein in the ration and is intermediate between the values of 3.6 percent obtained for suckling pigs by growth experiments (Sewell

et al., 1952) and 2.4 percent obtained for weanling pigs by tissue analysis experiments (Curtin *et al.*, 1952b).

The present experiment demonstrates the value of a semi-purified ration in which natural protein is fed at a low level and all essential amino acids but one are added in appropriate amounts to give a balanced protein. This principle has wide application in that it combines the economy of natural protein rations and the versatility of synthetic amino acid rations first used with rats (Rose, 1937) and used more recently with pigs (Mertz *et al.*, 1952).

The excellent rate of gain on this new type semi-purified ration containing only 13.2 percent protein showed that the proper balancing of a natural feedstuff, such as corn, with essential amino acids permits a substantial reduction in the protein requirement of the weanling pig. The recommended level of protein for a weanling pig (25 lb.) on a diet of natural feedstuffs is usually 18 percent of the total ration. These data definitely show that this level of protein can be lowered appreciably if all of the essential amino acids are supplied in the proper balance and amounts. The protein quality of the corn-amino acid ration containing optimum threonine was demonstrated by a protein efficiency of 3.1 (pounds gain per pound crude protein). This efficiency is greater than the values of 2.1–2.6 obtained with high quality natural proteins (Geurin *et al.*, 1951; Catron *et al.*, 1952).

Summary

Semi-purified diets containing corn and appropriate supplements of essential amino acids and other nutrients have been used to determine the threonine requirement of the weanling pig. When the diet contained 0.2, 0.4, 0.5, 0.6, or 0.7 percent L-threonine maximum gain and feed efficiency were realized with the 0.4 percent level. This value represents 3.0 percent of the crude protein.

The high quality of the protein in the corn-amino acid rations was shown by a protein efficiency of 3.1 pounds of gain per pound of crude protein. When the proper amounts and balance of essential amino acids were supplied, weanling pigs (weight 25 lb.) grew at a normal rate at a level of 13.2 percent crude protein in the diet.

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HIGH LEVELS OF ALFALFA IN THE RATIONS OF GROWING-FATTENING SWINE

V. R. Bohman,[1] J. F. Kidwell [1] *and* J. A. McCormick [2]

Nevada Agricultural Experiment Station

MANY western states do not produce sufficient cereal grains to support an adequate swine industry. However, high quality alfalfa may be produced on the majority of farms or ranches within these states. If more alfalfa could be used in swine rations, pork production could be greatly increased in these areas.

Alfalfa meal is generally added to the rations of growing-fattening swine only in amounts necessary to meet the animal's carotene requirement. Alfalfa intake has been restricted because it was presumed that swine could digest only a small amount of fibrous material. Ellis, Zeller and King (1942) stated that the most desirable level of legume hay for growing-fattening swine was 5 to 15 percent of the ration. Evvard (1929), Oliver and Potter (1930), Headley (1932) and Fargo, Bohstedt and Lacey (1941) stated growing-fattening hogs usually made the best gains and required the least amount of feed when the rations did not contain more than 5 to 6 percent fiber.

More recently, Forbes and Hamilton (1952) demonstrated that fiber from different sources varied widely in digestibility by swine and that the metabolic products of fiber and/or cellulose digestion were readily utilized. When alfalfa meal formed 23.6 percent of a balanced ration, 42.5 and 49.7 percent of the crude fiber and cellulose were digested, respectively.

Research was undertaken to determine whether high levels of alfalfa could be used satisfactorily in the rations of growing-fattening swine.

Experimental Procedure

Growth and feed utilization studies were conducted during the summer of 1951 and the spring and summer of 1952 in four separate trials. One hundred-and-two purebred Minnesota No. 1 and Minnesota No. 1×Duroc pigs were used in these experiments. They were allotted to each treatment according to weight, sex, litter and breed. The rations used are given in table 1. These feeds were ground, thoroughly mixed and self-fed so that no selection of any feed was

[1] Department of Animal Husbandry.
[2] Department of Farm Development.

TABLE 1. COMPOSITION OF RATIONS IN PERCENT

	Trial I			Trial II			Trial III	Trial IV
Ingredient	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Both lots[1]	Both lots[2]
Alfalfa	10	30	60	10	30	50	20	50
Barley	90	70	40	60	47	33	53	25
Wheat				30	23	17	27	25

[1] With or without 6.2 mg. terramycin per pound of feed consumed.
[2] Fed as pellets or meal.

possible throughout the experiments. In addition, protein supplements were fed *ad libitum*. In trials I, II and III this supplement consisted of 20 percent meat scraps, 20 percent fish meal, 30 percent cottonseed meal and 30 percent alfalfa. In trial IV, the supplement consisted of 33.3 percent each of meat scraps, fish meal and cottonseed meal. Prior to weaning, all pigs were creep-fed a mixture of 25 percent wheat, 50 percent barley and 25 percent alfalfa. No supplemental minerals were fed in any of the trials.

Body weights and feed consumption were noted at 14-day intervals throughout the experiments. Limited carcass measurements were also made.

Results and Discussion

The results of trials I and II are given in table 2. The alfalfa in the concentrate mixtures and protein supplements has been combined in order to indicate the total amount of alfalfa consumed. Prior

TABLE 2. THE EFFECT OF DIFFERENT LEVELS OF ALFALFA UPON GROWTH AND FEED UTILIZATION BY GROWING-FATTENING SWINE

	Trial I			Trial II		
Item	10% Alfalfa	30% Alfalfa	60% Alfalfa	10% Alfalfa	30% Alfalfa	50% Alfalfa
No. of pigs	10	10	10	10	10	10
Days of experiment	139	153	159	95	103	124
Average:						
Initial weight, lb.	23.4	23.7	24.0	34.2	34.0	34.1
Final weight, lb.	186.5	196.5	169.7	200.0	195.0	189.0
Daily gain, lb.	1.2	1.1	0.9	1.7	1.6	1.3
Lb. feed/100 lb. gain:						
Total	451.3	480.2	529.7	466.5	461.8	573.1
Grain	352.1	296.7	180.4	380.5	274.1	269.4
Protein supplement	53.4	56.4	78.7	30.6	29.2	25.2
Alfalfa [1]	39.1	127.1	270.6	55.4	138.5	280.2

[1] Total alfalfa in concentrate ration and free-choice protein supplement.

to the start of trial I, the pigs became infected with mange. Although a cure was effected as the trial progressed, the infection decreased the rate of gain in all treatments. Differences in rate of gain of the three groups of pigs were not significant at the 5 percent level. However, the observed rate of gain decreased with increasing levels of alfalfa. For this reason, 50 percent alfalfa was the highest level used in the second trial.

In trial II, more rapid gains were observed. As the level of alfalfa in the ration increased, the rate of gain decreased significantly. However, the observed differences in rate of gain between the two groups fed the lower levels of alfalfa is negligible. In these two trials it will be observed that the animals consuming 30 percent of their feed as alfalfa gained nearly as rapidly as those fed only 10 percent. Compared with the 10 percent alfalfa level, fair gains were obtained when the ration contained 50 to 60 percent alfalfa. More total feed but less grain was required as the level of alfalfa increased in the ration. One pound of alfalfa replaced from 0.5 to 1.0 lb. of cereal grain in these rations. At usual feed prices, these levels of alfalfa could be used to replace part of the cereal grains.

Since antibiotics have been shown to give a growth stimulus, trial III was designed to investigate the effect of terramycin on the rate of gain of swine fed high levels of alfalfa. These data are presented in table 3. No significant differences existed between the control pigs and those fed 6.2 mg. terramycin per pound of feed. These results are not in agreement with those of Brown and Luther (1950) or Hoefer *et al.* (1952). It is possible that an interrelationship exists between the alfalfa level and the antibiotic. Experiments have been designed to investigate further this problem.

Forbes and Hamilton (1952) demonstrated that the source of fiber affects its utilization by swine. Since it is possible that other factors affect the utilization of high alfalfa rations, a 50 percent alfalfa-grain mixture was fed as pellets and meal in trial IV (table 3). These results indicate that when a pelleted ration containing 50 percent alfalfa was fed to growing-fattening swine there was a significant increase in rate of gain as compared with the gain of swine fed the same ground mixture. In addition, much less feed was required per 100 lb. gain. No difference was noticed in feed wastage between the two groups. The pellet-fed group actually consumed less feed daily than the group fed the ground-feed mixture. These observations are in accord with those of Dinusson *et al.* (1951) who obtained increased

gains when a ground barley ration for swine was fed in pelleted form.

No significant differences were observed in the five primal cuts from a sample of pigs from each group in trial II. A marked enlargement of the stomach and intestines was observed in the groups which received 30 to 50 percent alfalfa. However, dressing percent was not affected significantly. Dressing percentages were 76.3, 75.0 and 72.6 for the groups receiving 10, 30 and 50 percent alfalfa, respectively.

TABLE 3. THE EFFECT OF TERRAMYCIN AND FEED PREPARATION ON GROWTH AND FEED UTILIZATION BY GROWING-FATTENING SWINE

Item	Trial III—20% Alfalfa		Trial IV—50% Alfalfa	
	Control	6.2 mg. Terramycin/lb. of Feed	Pelleted	Ground
No. of pigs	11	11	10	10
Days of experiment	112	112	76	76
Average:				
Initial weight, lb.	34.7	34.3	73.4	73.2
Final weight, lb.	188.9	198.8	202.1	184.2
Daily gain, lb.	1.4	1.5	1.7	1.5
Lb. feed/100 lb. gain:				
Total	434.8	427.3	558.5	698.2
Grain	323.7	324.5	263.0	322.2
Protein supplement	21.1	15.2	32.5	53.3
Alfalfa [1]	90.0	87.6	263.0	322.2

[1] Total alfalfa in concentrate ration and free-choice protein supplement.

Measurements of back fat thickness, length and dressing percentage were taken on 11 barrows from trial IV. Six were from the pellet-fed group and five from the meal-fed group. Back fat and length measurements were taken in accordance with U.S.D.A. specifications. There were no significant differences between groups. Averages for the 11 barrows were: Back fat, 1.47″; length, 30.8″; dressing percent, 73.4. Three carcasses graded choice #1 and eight graded medium. Indications are that medium and choice #1 carcasses are preferred on Nevada markets.

On the basis of the data obtained in these experiments, it can be concluded that growing-fattening pigs can make gains of the order of 1.3 to 1.7 pounds per day with 30 to 50 percent alfalfa in the ration. Results may vary because it appears that many factors affect the utilization of high roughage rations for swine. Additional work is being conducted to determine these factors.

Summary

Growth studies have been conducted with 102 growing-fattening pigs fed rations containing from 10 to 60 percent alfalfa. There was little difference in the rate of gain of pigs fed rations containing from 10 to 30 percent alfalfa. Fair gains were observed in the animals fed 50 percent alfalfa compared with those fed the 10 percent alfalfa level.

Terramycin fed at the rate of 6.2 mg./lb. of feed in 20 percent alfalfa rations failed to give a growth response.

A pelleted 50 percent alfalfa-grain mixture increased significantly the rate of gain as compared with the ground mixture.

Carcasses of the pigs grown on rations containing 30 to 50 percent alfalfa were graded medium, with a small proportion of choice #1.

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THE OPTIMUM CRUDE FIBER LEVEL IN RATIONS OF GROWING PIGS

JOEL AXELSSON and STURE ERIKSSON

Royal Agricultural College,[1] *Sweden*

A NUMBER of investigations with growing pigs (Lathrop *et al.*, 1938, and Nordfeldt, 1946) have proved that weight gain and feed efficiency reach their maximum at a certain level of crude fiber—the optimum level—in the dry matter of the rations. Further, in the experiments by Goldstein (1950), weight gain and feed efficiency were highest at a certain amount of ballast in the rations. According to Nordfeldt *(loc. cit.)*, the optimum was at 6.8–7.3 percent when the crude fiber content was raised by substituting oats for corn, but at 4.0 percent when wheat straw was substituted for corn. However, as Axelsson (1946) has pointed out, the number of pigs in the trials was so small that the difference may have been due to experimental error. Later on, Axelsson (1948) treated the data of a large number of trials carried out at several experiment stations in the U.S.A. (Beltsville, Wisconsin, Illinois, Indiana, and Ohio). According to these results, the optimum crude fiber content of the dry matter of the rations was between 5.5 and 7.0 percent, the variation thus being smaller than in Nordfeldt's trials, because of the greater number of animals in each series.

In all these experiments the crude fiber level was calculated as an average during the whole experimental time, thus in general from a body weight of about 30 kg. to about 100 kg. However, it is possible that the optimum should rise in the course of this period. In order to investigate this problem, experiments have been carried out at this Institute, the result of which will be given in the following pages.

Experimental Procedure

The investigation embraced four experiments, carried out successively from February 1951 to August 1952. Each experiment included four lots of four pigs each, the total number of pigs thus being 64. They were purchased at a body weight of about 20 kg. In each trial the pigs were of the same breed, either Large White English or Swedish Land breed. In the preliminary period all the pigs were fed

[1] Institute of Animal Nutrition.

the same feed mixture, the crude fiber content of which amounted to 6.6 percent of the dry matter. When the body weight reached 30 kg. the pigs of each experiment were divided into lots so as to give the greatest uniformity between lots with respect to sex, body weight and gain in weight. As the protein requirement of the pigs decreases during the growth period, three feed mixtures were used, the first from 30 to 50 kg. (period 1), the second from 50 to 70 kg. (period 2), and the third from 70 to 100 kg. (period 3). The crude fiber content of the dry matter of the rations was unchanged during the whole period of growth, but in each period it was increased from lot I to lot IV. The composition of the feed mixtures of the four lots in the different periods of growth is given in table 1.

In all the mixtures the dry matter content amounted to about 87.7 percent. The table shows that, by substituting ground wheat straw for grains, the crude fiber content of the dry matter of the feed mixtures was raised from 4.8 percent (lot I) to 9.3 percent (lot IV), the difference between two consecutive lots thus being 1.5 percentage units. The choice of wheat straw for regulating the crude fiber content depended on the indifferent nature of this foodstuff in all respects. The metabolizable energy was calculated by means of the digestion coefficients found in trials with swine and the factors of Axelsson (1939, 1949) giving the amount of metabolizable energy per gm. of digestible substance for swine. Its amount was expressed in mega-calories (mcal.), one mcal. containing 1000 kcal. or 1,000,000 cal. The amount per kg. of mixture decreased with an increased crude fiber content in the dry matter. In each period the amount of digestible protein—determined in trials with swine—per mcal. was practically equal in all the lots, but was continually decreased in the mixtures from the preliminary period to period 3. At the same time the content of animal protein in the total digestible protein was reduced. In each period the amounts of calcium and phosphorus per kg. of feed were practically the same in the four lots. On the other hand, in each lot the amounts decreased in the course of each experiment. The necessary vitamins were provided by dehydrated clover, dried yeast, and deltafor, containing at least 1000 I.U. of calciferol per gram.

The pigs were self-fed during the whole experiment. They were weighed once a week at the same time as the weekly feed consumption was determined. The wasted feed was included in that consumed. Under practical conditions the pigs are generally kept with straw bedding, and straw was therefore used in these experiments, too. A

TABLE 1. COMPOSITION OF THE FEED MIXTURES OF THE LOTS AND PERIODS

Item	Preliminary Period	Period 1				Period 2				Period 3			
Body-weight, kg.	20–30	30–50				50–70				70–100			
Lot	I-IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Crude fiber in dry matter of ration, %	6.6	4.8	6.3	7.8	9.3	4.8	6.3	7.8	9.3	4.8	6.3	7.8	9.3
Foodstuffs in the mixtures, %:													
Oats and barley mixture	76.0	35.1	33.5	31.9	30.4	34.6	33.0	31.4	29.9	37.9	36.2	34.5	32.9
Corn meal	7.0	50.0	48.0	46.0	44.0	53.0	51.0	49.0	47.0	53.0	51.0	49.0	47.0
Fish meal	4.4	4.0	3.9	3.9	3.8	3.0	2.9	2.9	2.8	1.9	1.9	1.9	1.9
Meat scrap	4.4	3.9	3.9	3.8	3.8	2.9	2.9	2.8	2.8	1.9	1.9	1.9	1.9
Clover meal dehydrated	6.2	5.0	5.0	5.0	5.0	4.8	4.8	4.8	4.8	3.8	3.8	3.8	3.8
Wheat straw meal	....	....	3.7	7.4	11.0	....	3.7	7.4	11.0	....	3.7	7.4	11.0
Dried sulphite yeast	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5
Deltafor (vit. D_2)	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Common salt	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Calcium carbonate	0.6	0.6	0.5	0.5	0.4	0.6	0.5	0.5	0.4	0.6	0.5	0.5	0.4
Bone meal	....	....	0.1	0.1	0.2	....	0.1	0.1	0.2	....	0.1	0.1	0.2
Nutritive value of the mixtures:													
Metabolizable energy, mcal./kg.	2.76	3.03	2.94	2.85	2.76	3.03	2.94	2.85	2.76	3.00	2.91	2.82	2.73
Crude protein, gm./kg.	161	155	152	149	146	145	141	138	134	132	129	126	124
Digestible protein, gm./kg.	132	125	122	118	115	115	111	108	105	104	101	98	95
" " gm./mcal.	48	41	41	41	41	38	38	38	38	35	35	35	35
Animal protein in digestible protein, %	40	38	39	40	40	31	32	32	32	22	23	23	24
Calcium gm./kg.	6.9	6.3	6.3	6.3	6.2	5.7	5.7	5.7	5.6	4.8	4.8	4.8	4.8
Phosphorus, gm./kg.	4.7	4.2	4.2	4.1	4.1	4.0	4.0	4.0	3.9	3.7	3.7	3.7	3.7
Ca/P ratio	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3

part of the straw was eaten by the pigs, so that the total amount of consumed crude fiber was greater than that of the feed mixtures. Naturally, therefore, the results postulate straw litter for the pigs. During the whole experimental time the pigs were kept indoors. The temperature of the barn was higher in summer than in winter, though the variation did not seem to have influenced the reaction of the pigs.

Results

In the preliminary period the daily gain in weight of the pigs averaged 500 gm. The daily feed consumption amounted to 1.43 kg., containing 3.95 mcal. of metabolizable energy. Thus, during this period, 7.76 mcal. were consumed per kg. of weight gain.

For each lot and period of the trial proper averages of the daily weight gain, the daily consumption of feed and energy, the feed energy per kg. of weight gain, the feed costs, and the dressing percentages of the pigs are included in table 2.

According to this table, in each period as well as over all periods, the average daily gain was highest in lot II and lowest in lot IV. When smoothing the averages by second degree polynomials the following equations were obtained (y denotes the daily weight gain in gm., and x the crude fiber content in percent of the dry matter of the feed).

Period 1: $y=418+67.8x-5.45x^2$
" 2: $y=590+63.6x-4.70x^2$
" 3: $y=496+110.3x-8.13x^2$
" 1–3: $y=498+82.1x-6.25x^2$

In figure 1 (upper curve) the equation of periods 1–3 is graphically represented. A test of the significance of departure from linear regression (Snedecor, 1946, p. 381) of the equation of this period showed that the ratio between the mean square of the curvilinearity of the regression and that of the deviations from curved regression lay about the 5 percent point. However, this result has to be compared with that of the corresponding test of the curvilinearity of the feed efficiency.

According to the equations, the maximum daily gain and the optimum content of crude fiber were the following:

	Maximum Gain, gm.	Optimum Crude Fiber, %
Period 1	629	6.22
" 2	806	6.77
" 3	870	6.79
" 1–3	768	6.57

It seems that the increase in gain of weight was greater from period 1 to period 2 than from period 2 to period 3. The average gain from 30 to 100 kg. of weight amounted to 768 gm., and was therefore very satisfactory. As a comparison it may be mentioned that in State Pig Testing in Sweden in 1951 the daily gain in weight

TABLE 2. AVERAGES OF DAILY WEIGHT GAIN, DAILY FEED CONSUMPTION, FEED EFFICIENCY, FEED COSTS, AND DRESSING PERCENTAGES IN THE LOTS

Item	Lots			
	I	II	III	IV
Crude fiber in dry matter of ration, %	4.8	6.3	7.8	9.3
Daily gain, gm.				
Period 1	617	631	613	578
" 2	784	813	791	778
" 3	831	890	840	826
" 1–3	745	778	748	725
Daily food consumption, kg.				
Period 1	2.05	2.01	1.98	2.09
" 2	3.04	2.93	3.06	3.24
" 3	3.64	3.68	3.69	3.76
" 1–3	2.93	2.89	2.93	3.02
Daily energy consumption, mcal.				
Period 1	6.20	5.91	5.65	5.76
" 2	9.20	8.62	8.73	8.93
" 3	10.92	10.71	10.41	10.26
" 1–3	8.85	8.46	8.32	8.31
Energy per kg. of weight gain, mcal.				
Period 1	10.05	9.37	9.21	9.97
" 2	11.73	10.60	11.04	11.48
" 3	13.14	12.04	12.39	12.42
" 1–3	11.87	10.88	11.12	11.47
Feed costs in periods 1–3				
Per kg. of feed, öre	41.0	40.6	40.2	39.8
Per kg. of weight gain, öre	161.5	150.8	157.3	170.2
Dressing percentage	73.2	72.9	72.7	73.5

from 20 to 100 kg. averaged 661 gm. in the Large White English breed and 650 gm. in the Swedish Land breed, though in this test the pigs were from the best sows of the best herds in the country. Further, it appears that the optimum crude fiber level lay between the contents of the mixtures of lots II and III, but nearest that of the mixture of lot II. The optimum seemed to be unchanged in the course of the growth of the pigs.

The average daily feed consumption increased from period 1 to period 3. In each of the periods there was a tendency to increase from lot I to lot IV, proving that in a certain degree the pigs compensated for the lowered amount of energy in the feed at a raised crude fiber content. However, in spite of this increase the daily feed energy decreased from lot I to lot IV. In each period as well as during the whole experimental time the metabolizable energy per kg.

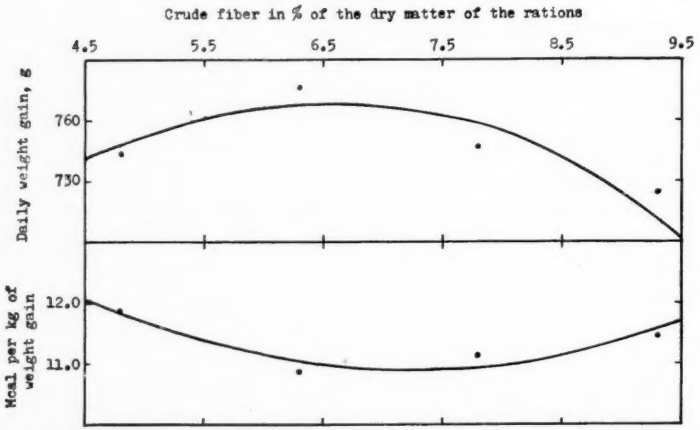

Figure 1. Averages of daily weight gain in gm. (upper curve) and of metabolizable energy in mcal. per kg. of weight gain (lower curve) in the 4 lots of pigs. The equations given in the text are graphically represented by these two curves.

of weight gain was, according to the table, lowest in lot II. On smoothing the data by second degree polynomials, the following equations were obtained (y denoting the amount of metabolizable energy in mcal. per kg. of weight gain, and x the crude fiber content in percent of the dry matter of the feed).

Period 1: $y=17.3-2.28x+0.160x^2$
" 2: $y=19.5-2.48x+0.174x^2$
" 3: $y=19.2-1.89x+0.126x^2$
" 1–3: $y=18.8-2.16x+0.149x^2$

In figure 1 (lower curve) the equation of periods 1–3 is graphically represented. A test of the departure from linear regression of this equation proved that the ratio mentioned above was greater than the 1 percent point, the curvilinearity thus being highly significant.

It follows also that the curvilinearity of the regression of gain in weight may be regarded as significant. According to the equations, the minimum energy per kg. of weight gain and the optimum crude fiber content in each period were the following:

	Minimum Energy per kg. of Gain, mcal.	Optimum Crude Fiber, %
Period 1	9.20	7.13
" 2	10.72	7.13
" 3	12.12	7.50
" 1–3	11.03	7.26

It seems that the minimum energy per kg. of weight gain increased from period 1 to period 3. On an average, from 30 to 100 kg. of weight, 11.03 mcal. were spent per kg. of gain. Further it seems that the optimum crude fiber content lay between that of the feed in lots II and III, but nearest that of the mixture in lot III. No change of the optimum appeared in the course of growth of the pigs. On an average 7.26 percent of crude fiber in the dry matter offered the best effect of feed energy. This optimum was 0.69 percentage units higher than that for maximum gain in weight, proving that a smaller daily amount of energy than that causing maximal weight gain yields the highest efficiency. Thus, it is a well-known fact that the feed consumption has to be slightly restricted when the pigs are on rations composed of corn, barley, and animal feed, in order to obtain the highest possible energy effect. If, instead, the crude fiber content of the dry matter of the rations is increased, a restriction is obtained, though the pigs are allowed to eat *ad libitum*.

From the next part of the table it appears that the cost per kg. of feed decreased as the content of crude fiber was increased (an increased amount of straw meal), though the decrease was relatively slight. The feed cost per kg. of gain in weight, on the other hand, was lowest in lot II and highest in lot IV. On smoothing the values by a second degree polynomial, the following equation was obtained (y denoting the cost in öre per kg. of gain in weight, and x the crude fiber content in percent of the dry matter of the feed mixtures).

$$y=268--34.8x+2.62x^2$$

This equation gives a minimum feed cost of 152 öre per kg. of gain in weight at a crude fiber content of 6.64 percent. Thus, the economical optimum of the crude fiber nearly agreed with the optimum of gain. Since the economical optimum was very pronounced, the

balancing of the rations as to crude fiber content is an important procedure.

Lastly, the average dressing percentage of the lots varied between 72.7 percent and 73.5 percent. The variation was independent of the crude fiber content of the feed mixtures. The average amounted to 73.1 percent, the loss thus being 26.9 percent. In this percentage was included the loss of weight in transporting from the barn to the slaughter-house. This loss was relatively great because the pigs were allowed to eat *ad libitum* until they left the barn.

The fatness of the carcasses of the pigs varied in some degree. The distribution of the pigs from the four lots was the following:

	Moderate Fatness	Slightly Overfat	Too Fat
Lot I	9	5	2
Lot II	11	3	2
Lot III	11	5	..
Lot IV	12	3	1

These data suggest that there was a tendency for the carcasses to decrease in fatness when the crude fiber content of the feed was raised. However, this tendency was very slight since the constitution (type) of the pigs highly influences this character.

Discussion

According to the present results the optimum content of crude fiber in the dry matter of the rations averaged 6.57 percent as to gain in weight, but 7.26 percent as to the efficiency of the metabolizable energy, the economical optimum being at a content of 6.64 percent. As to the fatness of the carcasses, the content in lot IV, 9.3 percent fiber, presented the best result, owing to the preference for a relatively lean pork in the Swedish market. In practice, when pigs are fed *ad libitum* from self feeders circumstances may justify the variation of the crude fiber content of the dry matter. If a pork of a moderate fatness is in demand, the content can be kept at about 6.6 percent since this content is optimum for gain in weight. However, an increase of the content to about 7.3 percent will raise the efficiency of the energy, and at the same time the fatness of the carcasses tends to lessen slightly. Very often this content may be the most economical too. In extreme cases, where a very lean pork is required, the content can be raised still further, though weight gain and feed efficiency are then lessened. Thus, the crude fiber content is a very important factor in balancing the rations.

The gain-in-weight optimum of crude fiber of 6.57 percent almost agreed with the value found by Nordfeldt regarding rations having varying amounts of oats, but not with that of rations containing varying amounts of wheat straw. In the present experiments wheat straw itself was used for varying the crude fiber content. As mentioned in the introduction, the number of pigs in Nordfeldt's trials was too small to draw such a conclusion.

The present optimum agrees well with that found by Axelsson *(loc cit.)*. In the experiments studied by him the crude fiber content was varied by means of oats, oat hulls, and hay meal, a great number of feeds having been investigated. In all the trials hitherto carried out variation in the estimates of the crude fiber optimum from one series to another seems to have been caused mainly by experimental error, since wheat straw was used in trials yielding the lowest as well as the highest optimum level. However, this conclusion may be restricted to normal feeds. Thus, when Goldstein *(loc. cit.)* used sawdust the result deviated greatly from that of normal feeds.

The result is important also in discussing the basis of feed evaluation for domestic animals. Thus, in Scandinavian countries the effect of individual feeds was determined in trials with milk cows and growing pigs in the case of exchanging one feed for another in the ration. In the present experiments a grain mixture of oats, barley, and corn was exchanged for wheat straw in amounts increasing from lot II to lot IV. Consequently the amount of grain mixture replaced by 1 kg. of wheat straw can be calculated. By using the smoothed values of period 3 the results will be the following:

	Lots			
	I	II	III	IV
Daily gain in weight, gm.	838	869	862	819
Energy per kg. of weight gain, mcal.	13.05	12.31	12.13	12.51
Maintenance energy in the time of 1 kg. of gain, mcal.	3.20	3.09	3.11	3.27
Mcal. spent for energy in 1 kg. of gain	9.85	9.22	9.02	9.24
Kg. of feed spent for energy in 1 kg. of gain	3.285	3.169	3.198	3.385
Weight gain in kg. per 100 kg. of feed	30.44	31.56	31.27	29.54

From lot I to lot II, in 100 kg. of the feed mixture, 3.7 kg. of wheat straw was substituted for 3.7 kg. of grain mixture, the result of which was an increase of gain in weight of 1.12 kg. This increase of

gain corresponded to $3.285 \times 1.12 = 3.679$ kg. of grain mixture, so that the effect of 3.7 kg. of straw equalled that of $3.7 + 3.679 = 7.379$ kg. of the mixture. It follows that, as to efficiency, 1 kg. of straw corresponded to 1.99 kg. of grain mixture. When all possible comparisons were carried out, the following series of amounts of grain mixture replaced by 1 kg. of straw was obtained:

Compared Lots	Grain Mixture Replaced by 1 kg. of Straw
I–II	1.99 kg.
I–III	1.37 kg.
II–III	0.75 kg.
I–IV	0.73 kg.
II–IV	0.12 kg.
III–IV	—0.54 kg.

According to this series, the compensation value of 1 kg. of wheat straw varied from 1.99 kg. to —0.54 kg. of grain mixture. Since comparisons of unbalanced rations underlie the feed values of the two European systems of feed evaluation, these values are not reliable. However, today it may be regarded as settled that, on the whole, constant net energy values of individual nutrients or feeds cannot be spoken of. The above calculation illustrates the correctness of this view.

Summary

The optimum crude fiber level in rations of growing pigs was studied in 4 experiments of 4 lots each, and of 4 pigs in each lot, the total number of pigs being 64. The pigs were fed *ad libitum* from self feeders. Each experiment embraced a preliminary period from 20–30 kg. of body weight. The trial proper was divided into three periods: period 1 from 30 to 50 kg., period 2 from 50 to 70 kg., and period 3 from 70 to 100 kg. of weight. The rations were balanced in all respects, with the exception of crude fiber content. By substituting wheat straw meal for grain, this content was raised from 4.8 percent (lot I) to 9.3 percent (lot IV) of the dry matter of the feed mixtures. The feed evaluation was based on metabolizable energy determined in experiments with swine.

The daily amount of consumed feed increased, though in a slight degree, with increased crude fiber content. On the other hand, the daily amount of metabolizable energy decreased at the same time. A crude fiber content of dry matter of 6.57 percent was optimum as to gain in weight, and a content of 7.26 percent as to feed efficiency.

The economical optimum was at 6.64 percent. The maximum daily gain in weight of the pigs averaged 629 gm. in period 1, 806 gm. in period 2, 870 gm. in period 3, and 768 gm. in periods 1–3 (from 30 to 100 kg. of weight). The minimum of metabolizable energy per kg. of weight gain averaged 9.20 mcal. in period 1, 10.72 mcal. in period 2, 12.12 mcal. in period 3, and 11.03 mcal. in periods 1–3. A tendency to lessened fatness of the carcasses appeared when the crude fiber content was raised. Finally, the importance of balancing the rations as to their crude fiber content is discussed.

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ABSTRACTS OF PAPERS TO BE PRESENTED AT THE FORTY-FIFTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Hotel Sherman in Chicago on November 27 and 28, 1953. Abstracts have been submitted for the following papers.

Breeding and Genetics Section

J. A. Whatley Jr., *Chairman*

TECHNIQUE FOR OBTAINING A CONTINUOUS RECORD OF MATING BEHAVIOR IN EWES. F. C. Bock, M. A. Schooley, Sanford L. Steelman and Irby Bunding, *Armour and Company.*

A method for the indirect observation of day-to-day mating behavior in a flock of sheep is described and its reliability is assessed. Approximately 705 ewes and 30 rams were penned together for 71 days, commencing on October 14, 1950. Marking crayons were attached to the briskets of the rams by commercial marking harness. On daily inspection of the flock any crayon marks on the rumps of the ewes were covered over with quick-drying white paint. Re-marked ewes were treated in the same way as those marked for the first time. A total of 1,051 marks was observed, a mark being defined as all pigment transferred from rams to a ewe during one day. By reference to the dates of delivery of lambs it is estimated that during the breeding trial only about 15 marks were incurred while the ewe was not actually in heat, but that ewes were covered by rams on about 62 occasions with no mark detected. Data obtained on the length of the estrual cycle, on the duration of estrus, and on the length of gestation are in consonance with findings obtained by other techniques as reported in the literature. A significant tendency was noted for ewes to accept rams during the period from about 3 to 10 days prior to the date of successful mating. All of the marks answering this description were incurred during the first 17 days of the breeding trial.

PARALYZED HINDQUARTERS—A HEREDITARY DEFECT IN AMERICAN RED DANISH CATTLE. L. J. Cranek and N. P. Ralston, *Michigan State College.*

An investigation of the effects of inbreeding in the American Red Danish cattle population brought to light a hereditary defect as yet unreported in American cattle. Sixty-five afflicted animals—thirty-eight females and thirty-seven males—were reported in twenty-seven herds. This abnormality was present at birth and persisted until death of the affected individual from other complications usually at about two weeks. The affected calves lie on one side, usually with outstretched limbs and often with extremely bent rear hocks. Therapeutic attempts were of no avail. X rays showed no gross deformities of the vertebrae or limbs. Five-generation pedigrees were constructed of each defective calf, and it was found that twenty-one Red Danish sires could be classified as heterozygous for the condition. A test based

on the assumption that 12.5 percent of the progeny should be defective when heterozygous sires were mated to progeny of heterozygous sires showed the calculated value for this defect to be 12.24 percent with a Chi-square value of 0.0004. This suggests that a single autosomal recessive gene conditions the defect. A gene frequency analysis suggests that 25 percent of the American Red Danish cattle are heterozygous for the paralyzed condition. The Chi-square value for randomness of mating was 0.004.

RELATIONSHIPS BETWEEN AGE AT FIRST CALVING, PRODUCTIVE LIFE, AND FAT PRODUCTION AT FIRST LACTATION. H. P. Davis, *University of Nebraska.*

A study was made of 231 Holstein females, the daughters of 46 bulls, in the University of Nebraska herd. Twenty-seven bulls had three or more daughters each, five had two daughters each, and 14 had one daughter each. The ranges and averages for the different features for individual cows were as follows: age at first calving from 601 to 1562 days, with an average of 906.1 days; productive life (elapsed time from first calving to disposal) from 158 to 5133 days, with an average of 906.1 days; fat production at first lactation (corrected to maturity for 305 days, 2.X) from 267 days to 729 pounds, with an average of 481.8 pounds. The average number of daughters for each bull was 5.02. For each cow in the herd, an average of 1.19 daughters were produced that later entered the herd for replacement.

A statistical study of the several relationships showed the following: 1. Age at first calving with productive life—correlation r = .056 not quite significant; regression = .308 days of productive life for each additional day of age at first calving. 2. Age of first calving with fat production at first lactation—correlation r = .409 highly significant; regression = .22 pounds of fat for each additional day of age at first calving. 3. Productive life in the herd with fat production at first lactation—correlation r = .121 just below significance; regression = .0116 pounds of additional fat for each day of productive life.

LABORATORY AND FIELD STUDIES WITH FROZEN SEMEN. H. O. Dunn, H. D. Hafs and G. F. Young, *Wisconsin Scientific Breeding Institute.*

Sixty-six semen samples obtained at three weekly collections from each of 22 bulls were frozen to —79° C. and thawed rapidly at 38° C. The mean motility was 36.4% and the mean revival rate was 55.3%. The analysis of variance revealed a highly significant difference among bulls ($P<0.01$) and no significant difference among samples from the same bull ($P>0.05$).

Semen samples from 20 bulls were extended to give final concentrations of 5, 12 and 30 million spermatozoa per milliliter of frozen semen. The post-thawing motility means were 34, 38 and 47% respectively. The differences were highly significant ($P<0.01$).

Sixty-four semen samples from 27 bulls of five breeds were frozen and stored 30 hours and 14 days at —75° C. in a Dry-Ice chest and 14 days at —20° C. The mean motilities of samples stored 30 hours and 14 days at —75° C. were 38 and 31% respectively. All samples stored at —20° C. showed no revival after thawing. Fourteen samples frozen and stored at —75° C. for 0, 3 and 7 days gave mean motilities of 57, 53 and 53% respectively; and samples stored in a mechanical deep-freeze at —65° C. for 0, 3 and 7 days gave mean motilities of 57, 58 and 54% respectively.

A 28- to 35-day non-return rate of 84% for 89 first services was obtained

with frozen semen thawed in 40° C. water. A non-return rate of 84% for 84 first services was obtained with samples thawed in 5° C. water.

THE DEVELOPMENT OF A MINIATURE BREED OF SWINE—A PRELIMINARY REPORT. David C. England, L. M. Winters and L. E. Carpenter, *University of Minnesota.*

A project to develop a physiologically and anatomically normal genetically small breed of swine (mature weight about 60–70 pounds) was initiated in 1949 at the Hormel Institute of the University of Minnesota under the professional direction of L. M. Winters. Purposes of the project are to develop a new and more suitable animal for many kinds of medical and other laboratory research work, and to derive fundamental information about swine genetics. Animal breeding techniques used include: 1. crossbreeding to provide a wide genetic base; 2. inbreeding by a flexible system of mating best to best; 3. selection on the basis of performance. Major factors of selection are fertility, survival, slow growth rate, low mature weight, and body conformation. Data indicate that (1) all three basic stocks are contributing heredity for small size (2) the three-way-cross is superior to any of the two-way-crosses as a genetic foundation and (3) a marked decrease in weight for age and general improvement otherwise in each selected generation. These results have been obtained with the same breeding techniques used in developing highly productive commercial swine. They indicate that utilization of segregation and recombination of hereditary units for performance through appropriate breeding techniques can result in progress toward a given goal. As such they support the formation of lines for commercial use through crossing followed by careful inbreeding of animals selected on the basis of tested performance.

FURTHER STUDIES ON THE ESTIMATION OF CARCASS YIELDS IN BEEF ANIMALS. W. W. Green, *University of Maryland.*

Data secured from the same fifty steers previously reported have been studied to find the possibility of predicting the weights of grouped wholesale cuts of beef by use of measurements. The round, trimmed loin, and rib were grouped into "primal" cuts I and the same three cuts plus the cross-cut into "primal" cuts II. Live weight was found to be most highly correlated with primal cut groups I and II. Good prediction of the actual weights seemed obtainable in the absence of live weight by use of width of shoulders and circumference of heart girth ($R = 0.91$) for primal cuts I. Dressing percent was studied by correlating it with forty different measurements. The correlation with width of shoulders (0.30) was the only significant one of the group. Width of shoulders and width of hooks appeared to be of importance in the estimation of individual wholesale cuts as well as the primal cut groupings I and II. Depth of chest was found of little value in assisting with predictions. The results of the study indicate the desirability of studying objectively many of the beliefs now held in connection with judging practices.

ACCURACY OF EIGHT SITES FOR PROBING LIVE PIGS TO MEASURE FATNESS AND LEANNESS. L. N. Hazel and E. A. Kline, *Iowa State College.*

Pigs weighing about 210 pounds were probed immediately before slaughter. Measurements on the live hogs were correlated with carcass data, particularly percent lean cuts and percent fat cuts. Four different experiments have been conducted involving from 48 to 96 pigs each. While only two sites were probed in all four experiments, eight sites have been probed in one or more experiments. Corre-

lations between the percent lean cuts, percent fat cuts, and the depth of fat measured by probing are as follows: Behind shoulder over longissimus dorsi, —.69, +.76; Middle of back over the longissimus dorsi, —.55, +.54; Middle of loin over the longissimus dorsi, —.70, +.76; Middle of loin over the lumbar vertebrae, —.48, +.53; Top of ham, —.65, +.66; Tailhead, —.57, +.43; Side of shoulder, —.47, +.54; Side of ham, —.29, +.40. The correlation between four backfat measurements taken on the carcasses and the percentages of lean cuts and fat cuts were —.75 and +.79 respectively. These figures are interpreted as evidence that measurements at some of the sites reflect fatness and leanness as accurately as backfat measurements on the carcasses. The sites behind the shoulder, over the loin, and the top of the ham have greatest accuracy.

COMBINING ABILITY OF SEVEN INBRED AND FOUR NONINBRED STOCKS OF SWINE. H. O. Hetzer, R. E. Comstock and J. H. Zeller, *U. S. D. A. and North Carolina State College.*

Females from seven inbred lines, ranging from 24 to 44 percent in inbreeding, were crossed in all possible combinations with noninbred boars of the Berkshire (B), Chester White (C), Hampshire (H), and Poland China (P) breeds for litters in two successive years. The females were from the Landrace (1), Chester White-Landrace (2), Landrace-Duroc (3), Landrace-Duroc-Hampshire (4), Yorkshire-Duroc-Landrace-Hampshire (5), Landrace-Large Black (6), and Landrace-Poland China (7) lines developed at Beltsville. The 28 different crosses were represented by a total of 241 litters. The number of litters per cross varied between 6 and 10. Estimates of the general combining ability of the various lines and breeds and of the specific effects among crosses were obtained by the method of unweighted means and by least square analysis. The traits studied were litter size and litter weight at birth and at 21 and 56 days. Since the lines were used only as female parent, estimates of line differences include direct maternal influences whereas breed differences include only transmitted influences. Differences among lines and among breeds were quite large for the most part, although only the differences for litter weight at birth between lines were found to be statistically significant. The Landrace exceeded all other lines in direct and transmitted influence for each of the traits studied. The same was true for the Poland China when compared with the other breeds with respect to transmitted influence. The estimates of the combining ability among the lines for litter weight at 56 days were $g_1 = 21.6$, $g_2 = -16.8$, $g_3 = -9.1$, $g_4 = 5.3$, $g_5 = -6.1$, $g_6 = 17.9$, $g_7 = -12.8$. Analogous estimates for the breeds were $g_b = -12.9$, $g_c = 5.5$, $g_h = 3.9$, $g_p = 14.5$. Substantial but non-significant differences in specific effects were indicated for all traits studied.

GROWTH RELATIONS IN RANGE CATTLE. James F. Kidwell, *University of Nevada.*

Weight gains were available from 88 grade Hereford steers and heifers and 67 purebred heifers grown at the University's range station in northeastern Nevada. Weanling calves were wintered on wild native hay, run on summer range, grazed on fall aftermath and fed hay the second winter. These are distinct environmental phases of growth, typical of northeastern Nevada range. Weaning weight and gains made during the four periods provide the data. Gross correlations were determined from an intra-year, intra-feeding group analysis. None of the correlations involving weaning weight is significant. The positive correlation between the two winter feeding periods indicates the existence of a group of genes influencing adaptability to winter feeding. Correlations between succeeding periods are significant and

negative, indicating an inverse relation between adaptability to winter feeding and summer and fall grazing in this environment. Genetic, environmental and phenotypic correlations were determined from the purebred data. In general, the environmental correlations are of greatest importance. The genetic correlation between ranging and grazing periods is positive, as is the genetic correlation between winter feeding periods. Genetic correlations between winter feeding and summer and fall grazing periods are negative. Environmental influences are of greatest importance in determining the relation between gains at different periods, but a genetic influence exists.

HERITABILITIES AND REPEATABILITIES OF FLEECE AND BODY TRAITS OF RAMBOUILLET, TARGHEE AND COLUMBIA SHEEP BORN IN 1951. W. H. Kyle and C. E. Terrill, *U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory.*

Heritability estimates were obtained by the half-sib method for 13 weanling and 18 yearling traits, and repeatabilities from weanling to yearling age were obtained for 11 traits of Rambouillets, Targhees and Columbias born at Dubois, Idaho, in 1951. Heritabilities (corrected for inbreeding) were calculated for each sex for inbred lines of each breed and for non-inbred Rambouillets from data on all lambs weaned (1724), selected weanlings (980) and yearlings (980). Repeatabilities were obtained for the same groups and also within all type-of-mating groups for each sex and breed. All traits except index were unadjusted for environmental factors and inbreeding. Heritability estimates varied among groups but were generally high for clean yield (%), clean fleece weight, face covering, fiber diameter, grease fleece weight and staple length; intermediate for diameter grade, neck folds, body weight, weaning index, diameter variability and belly wool; and low for breech wool grade, condition, type, breech amount, fleece grade, side grade, density and breech grade score. Selection tended to decrease heritabilities for rams and to increase them for ewes (higher proportion selected). Breed differences in heritability appeared large in some cases but sex differences over all groups were not great for any trait before selection. Age changes in heritability were variable among groups. Repeatabilities were high for weight, face covering and staple length; intermediate for breech grade, type, neck folds, side grade and condition; and low for breech grade score, breech amount and belly wool. Repeatabilities, except those for belly wool, were generally higher than the heritabilities.

EFFECT OF BREEDING OF DAM ON WEANING WEIGHT OF RANGE CALVES. Fentress M. Peacock, W. G. Kirk and Marvin Koger, *Florida Range Cattle Experiment Station.*

A study was made of records of 264 cows and their 673 calves produced from 1945 through 1951 at the Range Cattle Experiment Station, Ona, Florida, to determine the breeding of dam which was most efficient in producing the heaviest calves at weaning. Cattle used were from the commercial herd which consisted largely of grade Brahman with a few grade Devon, Hereford, Shorthorn and Native cows. These cows were kept on a combination of improved and native pasture with no supplemental feeding. Cows were classified according to breeding as follows: grade English with no Brahman blood; less than ½ Brahman; ½ Brahman; those with more than ½ Brahman; Florida native cows. Bulls used were five Brahmans, one Shorthorn and two crossbreds (½ Shorthorn–½ Brahman). Calf weights were adjusted for years, sires and time of calving (early and late) and corrected for age and sex. The average weight of 673 calves at 180 days was 371.6 pounds. Deviations from the mean were —3.8 for calves from grade English

cows, +10.0 from cows of less than ½ Brahman, +23.0 from cows of ½ Brahman blood, +5.3 from cows of more than ½ Brahman blood and —35.0 for calves from Native cows. There was a highly significant difference in the weaning weight in favor of calves mothered by ½ Brahman cows.

A COMPARISON OF CERTAIN CARCASS CHARACTERISTICS OF BRAHMAN VERSUS BRITISH BREEDS OF STEERS. A. M. Pearson, Marvin Koger, W. G. Kirk, D. H. Kropf, R. B. Sleeth and J. F. Hentges Jr., *Florida Agricultural Experiment Station.*

A total of 62 steers going through the regular kill of a large slaughter house were selected as representative of the Brahman and various British breeds of beef cattle. Data were collected upon slaughtering and the Brahmans were compared to the British beef breeds as a group. The Brahman steers averaged 839 pounds on foot compared to 907 pounds for the British animals, with the difference being significant. The Brahmans had an average dressing percentage of 60.01 compared to 59.68 for the British steers. The British bred steers had a lower percentage of front quarter, lighter hides, and lighter shanks, with all differences being statistically significant. The carcasses of the British steers graded higher with the difference being highly significant. However, the Brahman steers had lighter digestive tracts with the difference being highly significant.

STUDIES ON BREEDING FAILURES IN DAIRY CATTLE. D. B. Roark, *Mississippi State College.*

Experiments aimed at the cause and prevention of breeding failures in dairy females have been conducted for the past three years. Gross anatomic and histopathologic studies on the reproductive tracts of 33 normal and 52 difficult breeding dairy females revealed that the difficult breeding animals had larger ovaries by weight and a more acid cervical and vaginal pH than did the normal breeding animals. Of the difficult breeding animals, 63.5 percent had infections in various parts of the reproductive tract and 28.8 percent had obstructions that would mechanically interfere with sperm and ova transport in the female genital tract. The uterine mucosa and cotyledons were so seriously eroded in 25 percent of the difficult breeding animals that normal fetal attachment could not occur which suggests that impaired fertility was due to faulty attachment rather than fertilization failure. Intrauterine injections of various antibiotics and sulfonamides were made on dairy cows failing to conceive on the first three services 60 days postpartum. Treatment was 93 percent effective as measured by conception on the 14 animals treated to date.

FURTHER STUDIES ON THE RELATIONSHIP OF SERUM PROTEIN BOUND IODINE LEVELS TO RATES OF GAINS IN BEEF CATTLE. David K. Stokes, Jr., Mary F. Futrell and H. O. Kunkel, *Texas Agricultural Experiment Station.*

Studies on the relationship of the level of serum protein bound iodine to rates of gain have been continued using over 150 Hereford and Angus beef calves, including bulls, steers and heifers, 8–14 months of age, in 4 feeding trials. Additional evidence has been obtained to indicate that there is an optimum level of protein bound iodine commensurate with good subsequent feed lot gain. Using the alkali incineration method of Barker *et al.* for the determination of protein bound iodine,

the optimum range of protein bound iodine appears to be between 5.0 and 6.8 μg of protein bound iodine per 100 ml. serum. The fastest gaining animals consistently fell within this range of protein bound iodine levels. Because of the interrelationship of environment and a number of heritable factors some animals with protein bound iodine levels within the "optimum" range may give a relatively poor response in the feed lot.

THE MINERAL, NITROGEN, AND MELANIN CONTENT OF CATTLE HAIR. R. G. Washburn, L. O. Gilmore, N. S. Fechheimer and H. L. Taylor, *Ohio Agricultural Experiment Station.*

The mineral, total nitrogen and acid insoluble melanin content of cattle hair obtained from herds in Ohio and elsewhere through the courtesy of the Holstein-Friesian Association of America, were analyzed. Total ash ranged from 0.85% to 2.70%. The ash from differently colored hairs was analyzed spectrographically. The following elements were found to be present: Mg, Fe, Na, Pb, Mn, Ca, Cu, Ag, Zn, K, P, B, and Ba. The total nitrogen content of white, red and black hair ranged from 13.4% to 14.4%. The melanin content of cattle hair ranged from 1.63% for white to 11.83% for black hair. The mean percentage values for white, Guernsey-red, non-Guernsey red and black hair, respectively, were 1.8, 3.3, 4.6, and 8.0%. The black hair from known heterozygotes for red averaged 6.8% as compared to 8.6% for the remainder of the blacks. These differences were statistically significant. Two other factors affecting melanin content appear to be season and the area of the body from which the sample was clipped. The melanin content of hair from the forehead was lower than that from other areas of the body sampled. Hair clipped during the summer appears to be higher in melanin than hair clipped during the winter.

HERITABILITY OF MILK PRODUCTION IN MILKING SHORTHORN CATTLE. T. S. Yao, W. M. Dawson and A. C. Cook, *U. S. D. A.*

The heritability coefficients of milk, butterfat and peak-daily-milk production of the first lactation of 163 Milking Shorthorn cows raised and milked at the Agricultural Research Center, Beltsville, Maryland, were calculated with the paternal half-sib correlation method. Of the 163 cows, 123 which had production records available on both the daughters and dams were used to calculate the coefficients using both the paternal half-sib correlation method and the intra-sire daughter on dam regression method. The heritability coefficients for milk, butterfat, and peak-daily-milk production were 28.4, 36.8 and 16.9%, respectively, for the 163 cows derived from the paternal half-sib correlation method. They were 14.2, 24.5 and 14.8% from the paternal half-sib correlation method and 71.1, 83.9 and 73.7% from the intra-sire daughter on dam regression method for the 123 cows. The differences between the estimates obtained from the paternal half-sib correlation method for the 163 and 123 cows and those from the intra-sire daughter on dam regression method suggested that the inheritance of these milk production characters from the sires and that from the dams were different. This was explained as possibly due to the selection practiced in the herd, the effect of epistatic genes and possibly to a maternal inheritance.

Meats Section

R. L. Hiner, *Chairman*

THE EFFECTS OF FEEDING SEVERAL KINDS OF FAT ON FEED LOT PERFORMANCE AND CARCASS CHARACTERISTICS OF SWINE. E. R. Barrick, T. N. Blumer, W. L. Brown, F. H. Smith, S. B. Tove, H. L. Lucas and H. A. Stewart, *North Carolina State College.*

Two experiments have been conducted starting with 10 week old pigs fed a control diet with no added fat and diets with 10% fat added. In the first experiment the fats were peanut oil, beef fat and ½ peanut oil and ½ beef fat. Rate of gain and feed efficiency were very similar for the pigs receiving the fat diets (2.30–2.37 lbs gain/day and 279–288 lbs. feed/100 lbs. gain) and were superior to the control diet (2.02 lbs. gain/day and 347 lbs. feed/100 lbs. gain). Fat back thickness was significantly greater on carcasses from pigs fed the added fat. The yield of primal cuts was not greatly affected by the fat diets. Iodine numbers of the fats and unsaturated fatty acids, principally linoleic, were influenced by the kind of fat in the diet. In the second experiment average daily gain and feed efficiency for the control and for the diets containing beef fat, soybean oil, cocoanut oil and a commercial grease respectively were: 1.68, 330; 1.81, 273; 1.68, 268; 1.88, 274 and 1.76, 278.

FATNESS OF PORK AS RELATES TO CONSUMER PREFERENCE. Eugene Birmingham, D. E. Brady and Jesse Grady, *University of Missouri.*

A study was conducted in the Spring of 1953 to determine consumer preferences for pork of different degrees of fatness. Approximately 600 households were selected to meet statistical sampling requirements. Of this number, 361 households participated in the study. Loin chops, ham slices, and sliced bacon from U. S. D. A. Choice #1 and Medium carcasses were used. The carcasses were slaughtered at a weight of approximately 205 pounds. The Choice #1 had an average back fat thickness of 41.5 mm. and the Medium carcasses had an average back fat thickness of 35 mm. Choice #1 carcasses had no appreciable faults in conformation, firmness or color. The Medium carcasses were appreciably deficient in firmness or color or slightly deficient in both. A higher percentage of the household preferred the Medium Grade to the Choice #1 Grade both before and after cooking.

RELATIONSHIP OF AREA OF LONGISSIMUS DORSI MUSCLE TO OTHER CARCASS CHARACTERISTICS. V. R. Cahill, T. S. Sutton and L. E. Kunkle, *Ohio State University.*

Pork carcass evaluation has been quite generally accepted for determining carcass worth and for selection of breeding animals. Many methods of evaluation have been devised and tested; some of the most reliable being both time consuming and expensive. The Ohio State University introduced into its pork carcass evaluation a measurement not commonly used, namely, the area of longissimus dorsi taken in cross section perpendicular to the vertebral column between the tenth and eleventh ribs. This cross section may serve as an index of the amount of lean in the carcass and it also shows the size and shape of the eye muscle which is of prime importance in merchandising pork at the retail level. Using a

limited number of samples from 190–230 pound average hogs the area of longissimus dorsi has been correlated (1) with the weight of the primal cuts and (2) with the percentage of live weight of the four primal cuts (ham, loin, shoulder, belly) and of the three primal cuts (ham, loin, shoulder).

THE CONTENT OF B-COMPLEX VITAMINS IN THE TISSUES OF PIGS FED VARIOUS LEVELS OF PROTEIN WITH AND WITHOUT AUREOMYCIN. J. W. Carpenter, A. M. Pearson, H. D. Wallace, F. H. Jack and Mike Milicevic, *Florida Agricultural Experiment Station.*

Tissues used in this study came from 54 pigs, which were fed rations containing either 14.3, 17.6 or 20.9% of crude protein. One half the pigs on each level of protein were supplemented with aureomycin, while the remainder were unsupplemented. B-complex vitamins were added to all rations. Following slaughter, one ham was removed from each carcass, and was skinned, boned and ground. Samples were packaged, frozen and stored at 0° F. until analyzed. On 14.3% protein, the thiamine content averaged 12.83 and 11.81 μg. per gram of fresh tissue for the pigs with and without aureomycin, respectively. On the 17.6% protein ration, the thiamine content averaged 11.68 and 11.53 μg. per gram with and without aureomycin, respectively. The pigs receiving 20.9% protein with aureomycin averaged 12.10 μg. of thiamine per gram of tissue compared to 13.61 for the unsupplemented animals. Riboflavin values averaged 0.96 and 0.95 μg. per gram at 14.3% protein, 1.12 and 0.96 for 17.6% protein, and 1.07 and 1.13 μg. per gram at 20.9% protein with and without aureomycin, respectively. The niacin content with and without aureomycin respectively, averaged 32.75 and 35.19 μg. per gram of tissue for the pigs on 14.3% protein, compared to values of 39.60 and 33.65 on 17.6% protein and 34.65 and 39.14 μg. per gram on the 20.9% protein ration.

THE EFFECT OF TYPE AND WEIGHT ON THE YIELD OF PRIMAL AND MISCELLANEOUS PORK CUTS. J. W. Cole, C. E. Riley, H. J. Smith and C. S. Hobbs, *University of Tennessee.*

Detailed carcass data were obtained on 250 head of hogs handled uniformly as to feed, fill and shrink at the University abattoir. They were divided into six weight groups, from 155 lbs. to 305 lbs. at 30 lb. intervals, and the recognized types—chuffy (small), intermediate and rangy (large). In this research problem the following observations were made: (1) A highly significant correlation exists between type and dressing percentage. Longer hogs with deeper chest measurements had the lowest dressing percentage. (2) Although rangy hogs had a higher percentage of their live weight in primal cuts, this advantage diminishes as the live hog weight approaches 300 pounds. (3) Rangy carcasses had 23.4% more spareribs of a leaner kind than the chuffy type. This same trend was observed for neckbones, heart, liver and tongue as well as the feet, tail and kidneys with the intermediate hogs fitting in between. (4) Chuffy hogs had 32.2% less of their kill weight made of viscera than longer, rangy hogs. (5) A standard shrink should not be used in carcass evaluation because of the significant difference in percentage of viscera or G. I. tract between different types of hogs at any given weight. (6) Kill weight is probably a more constant basis for determining cutting yields as the total percentage of primal cuts based on packer or shipper style carcasses decrease as the live hog weight increases.

A PRELIMINARY STUDY OF CARCASS QUALITY DATA FROM THE 12TH RIBS OF BEEF AS COMPARED TO THAT OF THE 9-10-11 RIB CUTS. R. M. Crown, *Louisiana State University.*

It has been found to be rather costly to conduct detailed carcass studies as outlined by the cooperative livestock research program. Insufficient funds and lack of facilities have made it necessary for many workers to obtain only limited carcass data at packing plants. In order to encourage the collection of more detailed carcass data on a larger number of animals, this somewhat streamlined and less costly method of obtaining beef carcass quality data was instigated. Animals used in this test were pure bred, cross bred, and high grade beef steers. In addition, there were steers of various beef breed crosses included. The carcasses used were as follows: eight heavy steer carcasses weighing from 581 to 894 pounds, thirteen medium weight carcasses from 430 to 535 pounds, and thirty-two light weight carcasses ranging between 307 and 424 pounds in weight. This experiment was designed to determine the correlation of the cooking data from the 12th rib cut and that of the 9–10–11 rib cuts from the left side of the same beef carcass. Similar roasts from the right side of the same carcass were used to compare physical and chemical composition correlations. An analysis of the data demonstrates that the correlation that exists between the major carcass quality characteristics of the 12th rib and the 9-10-11 rib cuts is highly significant.

THE EFFECT OF PROGESTERONE-STILBESTROL IMPLANTS ON RATE OF GAIN AND CARCASS CHARACTERISTICS OF STEERS. R. J. Deans, W. J. Van Arsdell, E. P. Reineke and L. J. Bratzler, *Michigan State College.*

Results are given of two trials testing the effect of combined progesterone-diethyl stilbestrol administration to steers. In trial I, eight steers were implanted subcutaneously in the neck with 1 gm. progesterone and 100 mg. diethyl stilbestrol pellets. Eight steers served as controls. The entire test period included 81 days of pasture alone and 121 days of pasture plus corn and protein supplement. The control steers gained 1.95 lbs. per day, dressed 59.2% and produced six choice and two good grade carcasses. The implanted steers gained 2.15 lbs. per day, dressed 58.7% and yielded two choice and six good grade carcasses. The implanted steers had larger livers and greater pelvic measurements. No differences were found in iodine number or moisture percent of the fat. In the second trial, a group of 16 steers averaging 1068 lbs. from a previous feeding experiment were paired as to previous gain, weight, grade, and general type. Eight steers were implanted subcutaneously in the neck with 3 gm. progesterone and 100 mg. diethyl stilbestrol pellets. A ration of shelled corn, protein supplement and corn silage was fed for the test period of 76 days. The control steers gained 2.16 lbs. per day, required 2040 lbs. feed per 100 lb. gain and averaged 1232 lbs. at the end of test. They dressed 63.4%, and produced four choice, and four prime carcasses. The implanted steers gained 2.68 lbs. per day, required 1775 lbs. feed per 100 lb. gain, and averaged 1282 lbs. at the end of the test. The seven implanted steers (one steer removed during experiment) dressed 62.4% and yielded four choice and three prime carcasses. No significant differences were found between lots in moisture, or iodine number of the fat and separable lean, fat, and bone.

THE INFLUENCE OF VITAMIN B_{12} AND AUREOMYCIN SUPPLEMENTATION IN THE RATION ON THE VITAMIN B_{12} ACTIVITY OF PORK MUSCLE. R. F. Kelly, R. W. Bray and P. H. Phillips, *University of Wisconsin.*

Ninety-six feeder pigs, averaging 45 pounds, were randomly distributed into 12 lots of eight pigs each in a study to determine the effect of supplementation

of the ration with vitamin B_{12}, aureomycin, and aureomycin and B_{12} on the amount of vitamin B_{12} deposited in the tissues of hogs. All lots were fed a corn, soybean oil meal, alfalfa meal ration. High, intermediate, and low levels of protein were fed to each of three groups of four lots each. The initial protein levels for the three groups were 20, 17, and 14%, respectively. The four lots within each protein level were fed as follows: lot 1, control ration; lot 2, control plus B_{12}; lot 3, control plus aureomycin; lot 4, control plus aureomycin and B_{12}. Samples of the longissimus dorsi muscle were removed posterior to the last rib, and the B_{12} activity determined. The level of protein fed did not affect significantly the treatment of the lots with aureomycin and B_{12}. The lots receiving B_{12} alone had an increased B_{12} activity of the muscle which was highly significant in the medium and low protein levels and approached significance in those at the high protein level. In a second trial only the high and medium protein levels were used; however, these groups were supplemented with other B-vitamins in addition to B_{12}. The depression of B_{12} deposition in the tissues was again found in the lots receiving aureomycin alone yet in this experiment the interaction of aureomycin and B_{12} was not present. There was again an increased deposition of B_{12} in the tissue of the B-vitamin supplemented lots.

WASTE BEEF FAT IN SWINE RATIONS WITH SPECIAL REFERENCE TO ITS EFFECT ON CARCASS CHARACTERISTICS. D. H. Kropf, A. M. Pearson and H. D. Wallace, *Florida Agricultural Experiment Station.*

Due to the relatively low prices of inedible animal fats in relation to other feed ingredients, four experiments involving a total of 73 pigs were conducted to determine the feeding value of raw ground waste beef fat in swine rations. Data were obtained upon slaughtering to ascertain the influence of the fat upon carcass quality. The fat was substituted for corn in a basal corn-soybean oil meal—meat and bone scraps ration at various levels with and without added B-complex vitamins. The protein level was equalized by adjusting the proportion of protein supplement, but no effort was made to adjust for differences in energy. The addition of fat to the basal ration increased gains and efficiency of gains, while adding B-vitamins resulted in a further improvement in the ration. Levels of 10 and 15% fat were fed successfully in the mixed ration, with the replacement value of the fat averaging 115% of corn. Neither added fat nor B-vitamins significantly influenced dressing percentage, fat back thickness, carcass grade or firmness of carcass as measured by Iodine Numbers or manual firmness grades. When the fat was hand-fed and the remainder of the ration self-fed, the pigs ate 18% fat. However, gains were unsatisfactory and the dressing percentage was lower. The carcasses had less back fat, more length and less firmness than those from pigs fed on the other rations.

THE APPARENT EFFECTS OF AGE OF CASTRATION ON PHYSICAL COMPOSITION OF HEREFORD MALES. L. E. Kunkle, V. R. Cahill, R. J. Deans, E. J. Briskey, F. E. Deatherage and E. W. Klosterman, *Ohio Agricultural Experiment Station.*

Three years study concerning the effect of sex hormones on fattening beef cattle and acceptability of the carcasses have been completed under auspices of the Ohio Agricultural Experiment Station. A discussion of only that phase of the project performed by the Meat Laboratory is the purpose of this paper. In each of the first two years the feeder calves were divided into three lots of ten and twelve head, respectively, for the years 1950 and 1951. The calves in Lot I were

castrated at one month of age. Castration of Lot II was delayed approximately five months and Lot III went to slaughter as bulls. A fourth lot designed to observe the effect of implanted hormone substance was added to the third trial begun in 1952. The 114 cattle were slaughtered and cut in the Meat Laboratory where a study was made of many factors, such as: dressing percentage, carcass grade, weight of blood, head, hide, paunch, quarters and wholesale cuts and the weight of fat, bone and trimmed edible portion of each wholesale region from the right side. Entire males proved to have higher percentages of head, hide and bone than did the steers. The average carcass grade consistently was highest in the early castrated lot, but edible portion (77+%) of the bull carcass exceeded the 73–74% edible portion yield of the steer carcasses. Meat eating qualities of the bull beef was acceptable.

THE INFLUENCE OF LIMITED-FEEDING, BY THE USE OF HIGH FIBER RATIONS, UPON GROWTH, FATTENING AND CARCASS CHARACTERISTICS OF SWINE. R. A. Merkel, R. W. Bray, R. H. Grummer, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Sixty-four hogs of mixed breeding were employed to study the effect of limited-feeding in dry lot by restricting the level of TDN in the rations from weaning to 210 pounds. A basal ration consisting of 18% protein and 76% TDN was diluted with corn cobs and alfalfa hay to obtain the medium (69) and low (62) levels of TDN. A control lot was hand-fed 70% of the basal. Restricting the level of TDN increased the length of the feeding period and depressed the average daily gain. The cost per unit gain is less in the hand-fed and medium TDN lots than the basal or the low TDN levels. In addition the dressing percentage and fat back thickness were decreased. The hogs from the restricted lots produced significantly leaner carcasses, and with the exception of the low TDN level on alfalfa hay, yielded superior-grading, firmer carcasses. The overall length of the carcasses was also significantly increased. No differences due to treatment were observed in the color of lean, areas of ham butt or the loin (eye muscle).

METHODS OF EVALUATING QUALITY IN BEEF. H. D. Naumann, D. E. Brady and A. J. Dyer, *University of Missouri.*

This investigation was conducted in an effort to determine the most usable methods for the quantitative evaluation of several factors usually associated with quality of meat. For most factors, existing methods were compared, but methods were developed where no adequate method existed. The carcasses and ribs from 38 two-year-old steers were used for the physical, chemical, and organoleptic determinations. The carcasses were predominately U. S. Choice grade, but also included U. S. Commercial, U. S. Good, and U. S. Prime. Low correlations existed between taste panel scoring for tenderness and the Warner-Bratzler or collagen content. Juiciness was more closely related to quantity of press fluid than to fat content of press fluid. The color of lean and fat was measured with the Photovolt Reflectance Meter and the Cary Reflectance Spectrophotometer. The Photovolt Reflectance Meter yielded results compatible with observed color whereas the Cary Reflectance Spectrophotometer was ill-adapted for work with meat. Results with the Photovolt Reflectance Meter may be expressed in terms of dominant wavelength of lean tissue and in terms of dominant wavelength and "whiteness" for fat tissue.

A COMPARATIVE STUDY OF THE EATING QUALITY AND BIOCHEMICAL CHARACTERISTICS OF THE MEAT FROM BULLS, STEERS AND BULLS TREATED WITH DIETHYLSTILBESTROL. Eugen Wierbicki, V. R. Cahill, L. E. Kunkle and F. E. Deatherage, *The Ohio Agricultural Experiment Station and The Ohio State University.*

The eating quality of the meat from bulls, early and late castrated steers, and bulls treated with diethylstilbestrol has been determined. The animals were studied on a three-year replication. All animals were 11–16 months old at slaughter. Although the meat from the bulls was somewhat less tender by comparison with that from the steers it was quite acceptable. A comparative biochemical study was made to determine, if possible, the relationship of certain biochemical and physical characteristics with tenderness. Hydroxy proline as a measure of total connective tissue, total hemoglobin, intramuscular fat; protein extractability; and total nitrogen have been determined. Also protein hydration has been studied. Total connective tissue (hydroxy proline) appears to be related to tenderness at 15 days post mortem to a greater degree than to tenderness at 3 days post mortem. The relative extractability of proteins in meat changes with post mortem age indicating significant changes in the proteins of the muscle plasma.

VARIABILITY AND HERITABILITY OF TENDERNESS AND ITS RELATIONSHIP TO OTHER BEEF CHARACTERS. T. S. Yao and R. L. Hiner, U. S. D. A.

The frequency distributions of the organoleptic tenderness scores and mechanical tenderness shear values of 298 beef and dual-purpose Shorthorn steers were normal except that the shear values of the beef Shorthorns showed a slightly bimodal distribution. The analyses of variance showed that organoleptic tenderness had highly significant difference between breeds, and shear value had no difference between breeds but highly significant difference between sires. The organoleptic score had 13.7% of the individual variance due to heredity and 86.3% due to environment while the shear value had 19.2 and 80.2% due to heredity and environment respectively. The variability coefficients for the whole population were 15.5% in organoleptic score and 22.3% in shear value. The variability for the dual-purpose Shorthorns was higher than that for the beef type in both organoleptic score and shear value. The heritability coefficients calculated with paternal half-sib correlation method were 30.3% for organoleptic score and 76.6% for shear value. The heritabilities for the beef and dual-purpose types were 1.7 and 48.8% for organoleptic score and 93.8 and 52.0% for shear value. Beef family 1 had 19.8% heritability for organoleptic score and 161.8% for shear value; the latter figure may be affected by the segregation of factors or the dominance and epistasis of the genes. Correlation studies showed that organoleptic score correlated closely with shear value (+0.44). The former correlated closely with that for eight other beef characters while the latter was correlated with only one of the 25 beef characters.

SIGNIFICANT RELATIONSHIPS IN PORK CARCASS EVALUATION. Steve Zobrisky, D. E. Brady, John F. Lasley, *University of Missouri.*

Carcass and live hog data from 207 hogs weighing an average of 208 pounds were used to find existing relationships between various measurements and yields. Significant negative associations were found between the four lean cuts and the live hog back fat probes. Similar, but somewhat lower relationships were found between the same measurements and the five primal cuts. Significant positive cor-

relations were found between the probes and total fat. Total lean showed significant positive relationship to the area of ham muscle and loin eye. Total fat was found to be highly associated with back fat thickness and to a lesser extent with body width and length. Cooler shrink and fasting shrink were found to increase with total lean and decrease with total fat and carcass weight. Trimming fat from regular hams decreased, with an increase in the yield of the four lean cuts, five primal cuts, loin and shoulder, and increased with total fat. Dressing percentage can be estimated from total lean, fat, and residual as well as from linear carcass measurements. Estimating equations have been developed and tested.

Nutrition Section

Elliot Barrick, *Chairman*

MODIFIED UREA SUPPLEMENTS WITH CORN SILAGE FOR WINTERING EWE LAMBS. W. W. Albert, U. S. Garrigus, R. M. Forbes and W. H. Hale, *University of Illinois.*

Two wintering studies were made using urea supplements with corn silage. The daily supplement fed each lamb contained amounts of nitrogen and energy equal to that in 0.25 pound (44%) soybean oil meal. Trace mineralized salt (sulfur free) and dicalcium phosphate were added to all supplements. Elemental sulfur was included in some supplements. Initially urea replaced two-thirds of the protein of 0.25 pound of soybean meal. Cerelose was added for energy. Average daily gains in pounds per lamb for 140 days were: soybean 0.137; urea-cerelose 0.115; urea-cerelose plus 0.5% sulfur 0.138; twice urea plus sulfur 0.141. Gains and nitrogen balances were not significantly different. Wool yields for urea-cerelose-sulfur while greater than for urea alone were not significant. Wool yields for soybean and for twice urea were statistically greater than for urea alone. In 1952–53 urea supplements were formulated without soybean meal. One source of energy was starch and cerelose and another was yellow corn. The study included a 37-day lot feeding period of silage and urea-starch-cerelose supplement followed by a 56-day individual feeding of regular silage and supplements. SO_2 treated silage was fed the last 28 days. Average daily gains in pounds per lamb for the 56-day period were: soybean 0.273; urea-cerelose-starch 0.173; urea-cerelose-starch plus 0.2% sulfur 0.209; urea-corn 0.225; urea-corn plus 0.2% sulfur 0.237. Nitrogen retention was lowest for lambs receiving urea-cerelose-starch without sulfur when fed regular silage, but their gains and nitrogen increased markedly upon feeding SO_2 silage.

RIBOFLAVIN REQUIREMENT OF WEANLING PIGS. C. B. Ammerman, D. E. Walker, R. M. Edwards, D. E. Becker and S. W. Terrill, *University of Illinois.*

Three tests were conducted to gain information concerning the riboflavin requirement of the weanling pig. Semi-purified diets of a similar nature were used in all tests. All pigs were individually fed *ad libitum* in wire screen-bottomed cages. A riboflavin depletion period preceded the experimental treatments. In the first test, three groups of six pigs each received diets containing 0.00, 0.80, and 1.40 mg. of riboflavin per pound. Satisfactory gains resulted in both supplemented

lots and no appreciable differences were noted in daily gains and efficiency of feed conversion. The pigs in Lot I made almost no gain during the seven-week test period and typical riboflavin deficiency symptoms became evident. In a second test, three groups of six pigs each received diets containing 0.6, 0.8 and 1.0 mg. of riboflavin per pound. Differences in feed consumption, daily gains, and efficiency of feed conversion failed to be statistically different. Another test was conducted to ascertain the possible effects of aureomycin and vitamin B_{12} supplementation upon the riboflavin requirement of the pig. Thirty-two pigs were allotted into eight lots from litter outcome groups. A suboptimum level of 0.4 mg. and an optimum level of 1.2 mg. of riboflavin per pound of diet was fed with and without aureomycin at 10.0 mg. per pound and with and without vitamin B_{12} at 15 mcg. per pound. Differences in daily gains between the riboflavin levels were highly significant whereas the other main effects and interactions failed to yield significant differences, except that aureomycin significantly increased gains over the basal during the first three weeks of the test.

RELATIVE IMPORTANCE OF DIETARY CAROTENE AND LIVER STORES OF CARTENE AND VITAMIN A FOR REPRODUCTION AND LACTATION OF BEEF COWS. F. H. Baker, L. S. Pope and Robert MacVicar, *Oklahoma Agricultural Experiment Station.*

Twenty Hereford cows which had raised calves on pasture the previous summer were divided into four lots and fed wheat straw, milo, cottonseed meal and minerals to meet the N. R. C. allowances for all nutrients except carotene. During the expeimental period (last five months of gestation and first three months of lactation) they received a crude carotene concentrate to provide the following allowances of beta-carotene per head daily: Lot I, none; Lot II, 60 mg. during gestation; Lot III, 300 mg. during lactation; and Lot IV, 60 mg. during gestation and 300 mg. during lactation. Blood, milk and liver biopsy samples were collected periodically from the cows and their calves for vitamin A and carotene analyses. The initial liver vitamin A reserves of the cow were quite variable (62 to 462 mcg./gm. of dry liver tissue). A rapid decrease in liver stores, which was not retarded by supplementation, occurred during gestation, whereas carotene supplementation during lactation spared liver stores of vitamin A. Neither the prepartum diet of the cows nor their liver stores at parturition affected the vitamin A content of the colostrum or the liver levels of the calves at birth. Carotene supplementation during lactation increased the vitamin A content of the milk and of the calves' plasma and livers, while the liver vitamin A reserves of the cows were less effective in this respect. Vitamin A deficiency symptoms were observed in two calves of Lot I and three calves of Lot II, while no such symptoms were observed in the calves of Lots III and IV, or in any of the cows.

AMINO ACID REQUIREMENTS OF SWINE—PHENYLALANINE. W. M. Beeson, E. T. Mertz and J. N. Henson, *Purdue University.*

Twelve Duroc weanling pigs averaging 25 pounds were divided equally into four lots and fed individually in separate pens. The basal ration was composed of 66% corn, 21.57% dextrose, 4.30% minerals, 5.48% essential amino acids (excepting phenylalanine), 2.15% di-ammonium citrate, 0.5% liver extract powder, proper amounts of the essential vitamins and terramycin (10 mg./lb. feed). In order to adjust for the amino acid deficiencies of corn, purified amino acids were added at the following levels: 0.047% L-arginine·HCl, 0.391% L-histidine·HCl·H_2O, 1.078% L-isoleucine-D-allo, 0.20% L-leucine, 2.25% DL-lysine·HCl, 0.512% DL-methionine, 0.490% DL-threonine, 0.178% DL-trypto-

phan, and 0.334% DL-valine. The basal ration contained 0.23% phenylalanine and 0.14% tyrosine from corn and 13% crude protein equivalent. DL-phenylalanine was added to the basal diet to supply the following levels of digestible aromatic amino acids (phenylalanine plus tyrosine): Lot I, 0.37%; Lot II, 0.46%; Lot III, 0.56%; and Lot IV, 0.66%. During the 28-day period on these diets the pigs made average daily gains of 0.55 lb. (Lot I), 0.85 lb. (Lot II), 0.80 lb. (Lot III), and 0.76 lb. (Lot IV) and consumed respectively 1.79, 2.34, 2.22, and 2.30 pounds of feed per pig daily. These data indicate that the minimum level of phenylalanine necessary for maximum growth and feed efficiency of weanling pigs is 0.46% of the total diet. This is based on the assumption that tyrosine at the level fed (0.14%) can replace an equivalent amount of phenylalanine. Further research will be needed to determine the percentage of phenylalanine that can be replaced by tyrosine.

THE COMPARISON OF UREA AND PROTEIN MEALS AS NITROGEN SOURCES FOR RUMEN MICROORGANISMS. I. J. Belasco, *E. I. du Pont de Nemours & Co.*

In vitro comparisons of urea with protein meals used for ruminants, i.e., soybean, linseed, cottonseed, and corn gluten meals, indicated the superiority of urea as a nitrogen source in promoting cellulose digestion by rumen microorganisms. The addition of urea to various feed proteins to make 1:1 mixtures on a nitrogen equivalent basis improved cellulose digestion without any adverse effect on urea utilization. These data indicated that high availability of nitrogen to the rumen bacteria is the key to efficient cellulose digestion.

Chromatographic analyses of volatile fatty acids formed in the artificial rumen indicated that urea promotes the production of higher levels of propionic acid and lower levels of butyric and valeric acids than equivalent amounts of the protein meals. In general no significant differences were noted for acetic acid and total acid production. It is suggested that high propionic acid production is the result of high cellulolytic activity in the rumen in the presence of a readily available nitrogen source such as urea.

THE FEEDING VALUE AND DIGESTIBILITY OF WOOD MOLASSES IN RATIONS FOR LAMBS AND STEERS. M. C. Bell, C. C. Chamberlain, C. S. Hobbs, Hamdy Kemp, W. H. Morgan and Paul Johnson, *University of Tennessee.*

Thirty-six feeder lambs were used in digestion trials and feeding trials in an effort to evaluate wood molasses for livestock feeding. Twelve grade steers averaging 575 pounds were also used in a comparison of wood molasses with cane molasses for animal feeding. In the studies with lambs, comparisons were made between rations of hay alone with rations containing three levels of wood molasses. Other comparisons were made with wood molasses substituted for corn in rations for lambs. These same comparisons were repeated with the percentage of protein held constant with the addition of cottonseed meal. Another phase of this experiment with lambs involved the comparison of wood molasses with cane molasses when added to hay at early, medium and late stages of maturity with and without added grain in the rations. The results of these digestion trials showed that the addition of wood molasses to hay rations significantly decreased the apparent digestibility of crude protein on the average by 8%, even if the percentage of protein in the rations was held constant. With the addition of wood molasses, the digestibility of NFE was increased with no significant changes in the digestibility of ether extract and crude fiber. When wood molasses was substituted for over half of the grain in lamb rations, there was a decrease in the digestibility

of crude protein with no change in the digestibility of NFE. In the feeding trials, lambs and steers fed wood molasses did not gain as rapidly as those fed cane molasses. Consumption of wood molasses was lower when compared with that of cane molasses in *ad libitum* feeding.

THE USE OF SODA AND VACCINATION AGAINST "OVEREATING" DISEASE AS CONTROL MEASURES FOR DEATH LOSSES OF FEEDER LAMBS IN THE DRYLOT AND ON WHEAT PASTURE OR SORGHUM STUBBLE. T. Donald Bell, Rufus F. Cox, Lewis A. Holland and A. B. Erhart, *Kansas State College.*

A summary of five years' experiments using sodium bicarbonate as well as a vaccine against enterotoxemia as preventative measures against death losses in feeding lambs, shows no consistent advantages in providing either soda in the diet or vaccinating the lambs. The tests have included approximately 2000 western lambs hand-fed and self-fed various drylot rations of varying proportions of grain and roughage. The tests were also conducted with approximately 1000 lambs being fattened on wheat pasture and sorghum stubble. The soda was fed mixed with the feed or water at the rate of 1/5 ounce per head daily or provided free choice. The vaccine used was Type D Bacterin (Clostridium perfringens) secured from the Corn States Serum Company and administered in a 5 cc dose a week to 10 days before the lambs were started on tests. Losses from "overeating" disease were very low in all of the experimental lambs except in the first year's test when soda appeared effective in controlling losses from overeating. In the four succeeding years the few lambs that have died from enterotoxemia have been distributed about equally between the lambs receiving soda, those vaccinated, and those untreated. The effect of the two treatments upon feed consumption and rate of gain has been very slight and inconsistent.

NUTRITIONAL REQUIREMENTS OF RUMEN MICROORGANISMS FOR CELLULOSE DIGESTION *IN VITRO*. O. G. Bentley, Steve Vanecho, C. H. Hunt and A. L. Moxon, *Ohio Agricultural Experiment Station.*

A two or three fold increase in the cellulose digesting activity of rumen microorganisms *In Vitro* occurred when the culture medium composed of cellulose, urea, minerals, and 0.1% glucose was supplemented with autoclaved rumen juice. The microorganisms were separated from strained rumen juice by centrifugation and the sediment suspended in an isotonic phosphate buffer solution containing 0.05% cysteine. Cellulose disappearance during a 48-hour fermentation was used as a measure of microbiological activity. In addition to rumen juice, the factor(s) is present in several natural products, including dried yeast and a hot water extract of alfalfa leaf meal or hay. The stimulatory effect of rumen juice can be replaced in part by known substances as the addition of a mixture of 9 B-vitamins, adenine, uracil, xanthine, and alfalfa or molasses ash doubled the rate of cellulose digestion. Further, it appeared that a combination of B vitamins and alfalfa ash was responsible for most of the increased activity but B-vitamins or ash alone showed little increase in activity.

EFFECTS OF FEEDING VARIOUS LEVELS OF AUREOMYCIN TO FATTENING LAMBS. J. H. Bridges, J. C. Miller, W. S. Kammlade, Jr., and H. O. Kunkel, *Texas Agricultural Expeiment Station.*

The effects of feeding various levels of aureomycin to fattening lambs were studied using 154 lambs averaging 56–64 pounds in weight, in three feeding trials.

In two of the trials the lambs were started on a relatively high concentrate diet (50% milo or milo and cottonseed meal and 50% alfalfa hay) and in a third trial, the lambs were started on a low concentrate diet (25% milo, 75% alfalfa hay). Aureomycin as a feeding supplement was fed at levels ranging from 1.1 to 4.3 mg. per pound of feed in the first trial, at the level of 5 mg. per pound of feed in the second and at the levels of 1.25, 5 and 15 mg. per pound of feed in the third trial. In all cases, the gains of the aureomycin fed lambs were equal to or slightly above the control groups. Differences in gain, however, were not statistically significant. An apparent improvement of 5–12% in feed efficiency was evident when aureomycin was fed at levels of 2.2 to 5.0 mg. per pound of feed. At the 5.0 mg. level, aureomycin gave most benefit when the lambs were started on feed using a low concentrate ration. Fifteen mg. aureomycin per pound of feed was apparently too high to result in improvement.

THE EFFECT OF FAT AND DIETHYLSTILBESTROL ON CELLULOSE DIGESTION BY SHEEP RUMEN MICROORGANISMS. C. C. Brooks, G. B. Garner, M. E. Muhrer and W. H. Pfander, *University of Missouri.*

Seven trials involving 130 artificial rumina indicated that the fat level had a critical effect upon cellulose breakdown by sheep rumen microorganisms and that the addition of diethylstilbestrol resulted in a substantial increase in cellulose digestion. The basal included 500 mg. of filter paper, 40 mg. casein, 10 mg. urea and 10 mg. ammonium carbonate, 5 ml. water, 10 ml. McDougall's artificial saliva and 10 ml. of rumen fluid. In these trials 10 mg. corn oil added to the basal ration increased cellulose breakdown an average of 8%, while 20 mg. decreased it 4.8%, 40 mg. decreased it 35% and 80 mg. resulted in 75% less digestion. The addition of 10 to 20 micrograms of diethylstilbestrol increased cellulose digestion an average of 9%. Consideably less total cellulose digestion and smaller differences due to fat and stilbestrol occurred during the spring when inoculum was drawn from sheep on fescue pasture than during the winter when the sheep were eating corn silage, lespedeza hay and grain. Lowest digestion resulted, however, in late summer when the sheep were fed cottonseed hulls and casein.

EFFECTS OF ARSENICAL SUPPLEMENTS ON GROWING-FATTENING LAMBS. L. L. Bucy, U. S. Garrigus, R. M. Forbes and W. H. Hale, *University of Illinois.*

Thirty-six black-faced, western, feeder lambs were individually fed in 1951 a good fattening ration of 50% ground alfalfa, 45% ground corn and 5% soybean oil meal. Potassium arsenite, arsanilic acid and 3-nitro-4-hydroxyphenyl arsonic acid were used at three levels each, 0.002, 0.004, and 0.006% of the ration. The lambs receiving the higher levels of the arsenical supplements made slightly grater gains, but the differences in rate of gain and feed efficiency were not statistically significant. Blood clotting time, rumen flora, parasite population as judged by fecal examination, histology of the adrenal, liver, and kidney, clostridia in the caecum, and wool yield were not apparently affected by any of the arsenical supplements. No symptoms of toxicity were noticed, and all carcasses graded prime. In 1952 sixty lambs similar to those fed the previous year received two rations differing in quality, one the 1951 ration and the other having 32% ground wheat straw substituted for 32% of the ground alfalfa. The levels of arsenicals fed were 0.006, 0.012, and 0.024% 3-nitro-4-hydroxyphenyl arsonic acid with potassium arsenite and arsanilic acid fed at equivalent levels on an arsenic basic. Gains were not significantly different on the good ration but were apparently improved on the poorer quality ration ($P<0.05$). Blood

clotting time, rumen flora, and wool growth were not apparently affected by any of the arsenical supplements. There was no evidence of toxicity of the arsenicals at any of the levels fed.

A STUDY OF PROTEIN LEVELS FOR FATTENING FEEDER LAMBS. Leon F. Bush, *Cornell University.*

Three experiments were conducted with 297 western feeder lambs ranging in weight from 38 to 75 pounds. In each experiment a 3 x 3 factorial arrangement of nine lots of eleven lambs each was used to determine the relative efficiency of various rations with total potein content (air-dry basis) of 10, 11 and 12%. This design also makes it possible to compare the feed-lot performance of lambs getting corn silage as the sole roughage with similar lambs fed 0.75 pounds and 0.5 pounds of alfalfa hay and a full feed of corn silage. Rate of gain, feed efficiency, and grade on foot were used to evaluate the rations. The level of total protein was controlled by adjusting the amount of linseed meal added to the ration. A Ca–P ratio of approximately 2 to 1 was maintained in the rations by adding ground limestone when necessary. The differences in the rate of gain or the grade on foot of the lambs fed the various rations were not significant. The lambs fed corn silage as the sole roughage required less ($P<.01$) feed per 100 pounds of gain than those fed 0.75 pound of alfalfa hay plus a full feed of corn silage. The feed efficiency decreased ($P<.05$) as the amount of hay in the rations was increased. No significant differences were found in the feed efficiency of the lambs fed rations containing 10, 11, and 12% total protein.

LYSINE AND/OR METHIONINE SUPPLEMENTATION OF CORN-SOYBEAN OIL MEAL RATIONS FOR PIGS IN DRYLOT. D. V. Catron, D. C. Acker, G. C. Ashton, H. M. Maddock and V. C. Speer, *Iowa State College.*

One hundred twenty-eight pigs were fed 12 and 14% protein corn-soybean oil meal rations fortified with vitamins, minerals and terramycin and supplemented with 0, 0.05, 0.10 and 0.15% L-lysine and 0, 0.025, 0.050 and 0.075% DL-methionine in all possible combinations. This allowed the use of a 2 x 4 x 4 factorial plan. The 32 ration treatments were assigned at random, in each of two replicates, to 32 lots of two Poland Chnia x Landrace x Duroc pigs each (one barrow and one gilt). The pigs were self-fed, from an average of 23 pounds to 100 pounds. Feed comsumption per pig averaged 3.64 pounds per day on both the 12 and 14% rations. Pigs fed the 14% rations gained significantly faster (1.32 vs. 1.14 lbs. per day) and on significantly less feed (328 vs. 279 lbs. feed per 100 lbs. gain), on the average, than those on 12% rations. On the 12% rations rate of gain and feed efficiency increased as level of lysine supplementation increased to the 0.10% supplemental level, then leveled off or declined (1.07, 1.11, 1.21 and 1.18 lbs. per day and 374, 322, 301 and 314 lbs. feed per 100 lbs. gain). Lysine supplementation of the 14% rations had no effect on rate of gain or feed efficiency. As lysine supplementation increased on the 14% rations, feed consumption significantly decreased; on the 12% rations the effect was not significant. Methionine supplementation exerted no significant effect on rate of gain or feed efficiency on either level of protein.

UTILIZATION OF INTRAVENOUSLY-ADMINISTERED CAROTENE IN CATTLE AND SHEEP. D. C. Church, Robert MacVicar, John G. Bieri, F. H. Baker and L. S. Pope, *Oklahoma Agricultural Experiment Station.*

Utilization of intravenously-administered carotent preparations was studied in 7 vitamin A deficient Hereford calves and 8 western wethers. The carotene

preparations were essentially molecular dispersions of carotene in water, stabilized with polyoxyethylene 20 sorbitan monopalmitate, and differed, therefore, from colloidal carotene suspensions previously employed in studies of this type. The carotene preparation was administered by injection into the jugular vein; blood samples were collected at intervals thereafter and analyzed for carotene and vitamin A in the plasma. The plasma carotene level showed a prompt rise from 12γ/100 ml. in calves to 307 at 10 minutes after injection; comparable values for wethers were 2 and 614. In calves, the carotene declined during the subsequent two hours to 85γ and remained near this level during the next 48 hours; substantial amounts of carotene remained in the plasma at 10 days after injection. In wethers, the carotene disappeared much more rapidly from the plasma falling to 12γ at 72 hours. No substantial change in plasma vitamin A was noted in the calves, indicating only minimal conversion of the pro-vitamin. This was substantiated by the progression of vitamin A deficiency symptoms in the calves following carotene administration despite appreciable circulating carotene in the blood plasma. In wethers, on the contrary, the vitamin A level rose rapidly and consistently during the first 9 hours from 21 to 48, declining gradually thereafter. These data strongly suggest a major difference in the metabolism of carotene between cattle and sheep and may account for the differences observed in plasma carotene in these species when on carotene-containing rations.

THE VALUE OF IMPLANTED ANTIBIOTIC PELLETS FOR SUCKLING PIGS. Albert J. Clawson, Ben E. Sheffy and John P. Willman, *Cornell University*.

Eleven litters of eight pigs each were used to study the value of various antibiotics when implanted subcutaneously in the ear of 2-day old pigs. Aureomycin, bacitracin, and procaine penicillin were the antibiotics tested. The respective antibiotics were added singly and in all possible combinations including a control within each litter. The average weights of the controls, aureomycin, penicillin, bacitracin, (penicillin-bacitracin), (aureomycin-bacitracin), (penicillin-aureomycin), and combination of all three antibiotics, respectively were as follows: second day 3.1, 2.9, 3.5, 3.2, 3.1, 3.3, 3.3, 3.3; tenth day 6.7, 6.0, 7.1, 6.7, 6.3, 7.0, 6.7, 6.9; third week 11.9, 10.6, 12.2, 11.5, 10.9, 12.0, 11.6, 12.5; fifth week 17.7, 15.9, 18.4, 17.1, 16.4, 17.3, 16.9, 18.6; eighth week 32.2, 30.7, 34.0, 32.1, 31.3, 30.2, 30.8, 34.0. In this study the various antibiotics as implanted had no influence on average daily gain of nursing pigs.

A STUDY OF COMPOSITION OF MISSOURI GROWN ROUGHAGES. W. H. Coninger and H. A. Herman, *University of Missouri*.

During the years 1950–51–52 inclusively, 219 samples of dried roughages and 29 samples of silage produced by Missouri dairymen were collected and analyzed. Alfalfa hay averaged 52% green color, 10% foreign matter, 51.5% leaves, 91.5% dry matter, 17.7% crude protein, 1.55% ether extract, 26.5% crude fiber, 10.9% lignin, 38.0% N-F-E, 9.7 micrograms carotene per gram and 7.61% ash. The ash in alfalfa hay averaged 1.31% Ca, 0.54% P_2O_5, 1.79% K, 0.29% Mg., 0.26% S, 0.24% Cl., 181 ppm Fe, 29 ppm Mn, 8.9 ppm Cu, 0.10 ppm Co., 17 ppm Zn, 13 ppm B and 0.18 ppm I. The same analyses were made on red clover, K. Lespedeza, ladino clover, soybean, timothy, red top, and bromegrass hay. K. Lespedeza hay averaged 42.7 micrograms of carotene per gram which was three to five times above carotene levels in other hays. The average percentage of ash and calcium was increased and the average percentage of P_2O_5 was decreased in second cutting alfalfa and red clover hay for the moisture deficient year 1952. Ladino clover was similar to third cutting alfalfa in composition. When grown in combination with each other bromegrass hay contained only 17–35% as much

calcium as first cutting alfalfa hay but otherwise they were similar in composition. Field Chopped hay had 5.5% less leaf and contained 2.30% less crude protein and had 2.80% higher crude fiber than loose hay. Stem crushed hay had a slightly higher leaf content and contained more carotene than baled hay. The dry matter content of grass silage ranged from 19 to 55% and from 1.5 to 6.7% protein on a fresh basis.

A MEAL MIXTURE SUITABLE AS THE ENTIRE RATION TO BE SELF-FED DRY TO PIGS WEANED AT TEN DAYS OF AGE. E. W. Crampton, *Macdonald College.*

This paper presents the results of feeding to an age of 56 days young pigs weaned at 10 days of age and placed on one of eight dry meal mixtures. The meal mixtures were self-fed and water was available in a separate font. The report covers three replicates of a trial designed as a 2 x 2 x 2 factorial in which two protein levels, two fat levels and two antibiotics were compared. It was found that pigs readily and usually within 48 hours learn to eat a dry meal ration; that there was no advantage in rations to which 5% corn oil was added to a mixture carrying naturally 2% ether extract; that choice of antibiotic was immaterial; and that on the average when provided with warm dry beds by radiant heated hover-covered slabs the pigs reached normal weaning age of 56 days at weights at least as heavy as comparable pigs that nursed mothers and in addition had access to creep fed "starter" ration. Of the 100 early weaned pigs fed to date, seven died during the tests, as compared to four over the same period among the 90 controls that were "sow-nursed" to the age of 56 days.

A STUDY OF DIETS (DRY) DESIGNED FOR WEANING THE BABY PIG AT AN EARLY AGE (10 POUNDS OR LESS). Frank M. Crane, *Land O'Lakes Creameries.*

Preliminary studies indicated that pigs could be weaned from the sow and placed on a dry ration at an earlier age than was heretofore thought possible. Ninety-nine pigs were used in a study to develop a dry formula which would promote optimum growth in the baby pig. All pigs used in this study were weaned from the sow at an average weight of 10 pounds or less and were lotted into groups of 4 or 5 pigs each on the basis of litter, weight, and sex. Whenever possible lots were replicated. All three trials were terminated when the pigs were approximately six weeks of age. The control group was fed a basal ration containing 35% dried skimmilk, 10% dried whey, 4% lard, 1% soybean lecithin, 25% rolled oats, 25% ground corn and appropriate vitamin, antibiotic, and mineral fortification. To study the value of fats in the baby pig's diet rations containing 7.5, 10.0, 12.5, and 15.0% fat were fed. The pigs fed the 10.0% fat ration made the most rapid gains. They weighed 30.25 pounds at 45 days of age and required only 1.55 pounds of feed to make a pound gain. A second and third trial were designed to determine the optimum level of dried skimmilk. Rations containing 0, 13, 20, and 40% dried skimmilk were fed. The pigs receiving the ration containing 40% dried skimmilk made the most rapid and efficient gains.

COMPARISON OF EFFECT OF LEVELS OF AUREOMYCIN ON REPRODUCTION IN SWINE. Robert J. Davey and J. W. Stevenson, *U. S. D. A.*

Nineteen sows and gilts were divided into four groups, three of which were fed different levels of aureomycin. The levels of 10, 50, and 100 mg. of aureomycin per pound of diet were added to a basal ration of yellow corn meal, soybean

oil meal, alfalfa meal, and a complex mineral mix. The groups were placed on test at breeding time and maintained on the diets until their litters were weaned. Eight gilt pigs from each of the groups were continued on the same diets received by their dams. These gilts were bred and carried through a farrowing season. Thus, two generations of brood sows received the same continuous level of aureomycin. The three aureomycin-supplemented groups showed little variation in respect to appearance of estrus, conception rate, and number of litters farrowed, but they did show an advantage over the control group in the second generation where only three out of seven control gilts conceived while 18 out of 24 of the gilts receiving aureomycin were bred and conceived. There was no significant difference in litter size or in birth weights among the groups. However, the weaning weights of the aureomycin-fed animals were significantly greater than those of the controls ($P=0.01$).

AVAILABILITY OF PHOSPHORUS IN DEFLUORDINATED PHOSPHATE FED TO CATTLE AFTER ACTIVATION IN THE PILE. George K. Davis, L. R. Arrington and J. C. Outler. *Florida Agricultural Experiment Station.*

Defluorinated phosphate containing slightly in excess of 17% P was placed in the pile at Oak Ridge and through irradiation a portion of the P^{31} was converted to P^{32}. The labeled defluorinated phosphate was included in the rations of young cattle and, following a balance study, the animals were sacrificed to determine distribution of phosphorus in the tissues. By labeling the phosphorus in the compound a direct measure was obtained of the availability of the phosphorus from this source in comparison with phosphorus from KH_2PO_4. A parallel experiment was run simultaneously using rats as the experimental animals. The phosphorus from defluorinated phosphate was comparatively as available to calves as was the phosphorus of KH_2PO_4. Of 0.04 percent phosphorus from defluorinated phosphate in the ration approximately 70 percent was absorbed and utilized by the animals.

THE EFFECT OF TEXTURE ON THE DIGESTIBILITY OF OATS AND A MIXED CONCENTRATE BY RUMINANTS. R. F. Davis, J. K. Loosli and C. H. Grippin, *Cornell University.*

Widespread interest in the use of coarse textured concentrates has prompted investigation of the nutritive value of these feeds compared to finely ground concentrates. Four replicates of a 3 x 3 latin square design experiment were conducted to test the relative digestibility of crimped vs. ground oats by growing and lactating ruminants. Two replicates of a similar study were conducted comparing a coarse textured dairy ration vs. the same concentrate, finely ground. Digestion coefficients, calculated by difference, for the crimped oats were: dry matter 74.4, crude protein 75.7, ether extract 91.2, crude fiber 35.8, nitrogen-free extract 81.9. Those for the ground oats were: dry matter 71.8, crude protein 73.6, ether extract 88.6, crude fiber 27.6, nitrogen-free extract 81.1. Digestion coefficients obtained by difference for the coarse textured concentrate were: dry matter 82.2, crude protein 82.6, ether extract 61.2, crude fiber 25.9, nitrogen-free extract 90.5. Those for the finely ground concentrate were: dry matter 80.8, crude protein 82.0, ether extract 73.3, crude fiber 15.6, nitrogen-free extract 88.8. The calculated TDN content of the grains were as follows: crimped oats 69.6%, ground oats 68.4%, coarse-textured concentrate 71.7%, fine-textured concentrate 71.0%. None of the differences was statistically significant. Although the coarse textured grains gave very slightly higher digestion coefficients, there appears to be no real advantage in digestibility for any grain texture studied.

THE QUANTITATIVE LEUCINE REQUIREMENT OF THE SUCKLING PIG. R. G. Eggert, H. H. Williams, B. E. Sheffy, E. G. Sprague, J. K. Loosli, and L. A. Maynard, *Cornell University*.

Data from 2 trials involving 30 two-day old Yorkshire pigs are reported. The pigs were divided into 5 groups and individually fed simulated milk diets in which the protein nitrogen was supplied by casein, crystalline amino acids, and ammonium citrate (dibasic). L-leucine was added to the 5 experimental diets so as to provide the following levels of L-leucine in the diets (expressed as percent of air-dry matter): Lot I, 1.00%; Lot II, 1.25%; Lot III, 1.50%; Lot IV, 1.75%; and Lot V, 2.00%. The average daily gain in grams and the kilograms of dry matter required to produce a kilogram of gain for each of the five levels of L-leucine over a 3 weeks experimental period were 153, 194, 183, 199, 203 grams and 1.82, 1.41, 1.47, 1.36, 1.33 kilograms, respectively. These data indicate that the minimum level of L-leucine necessary for maximum growth and feed efficiency of suckling pigs fed a diet of this type containing 25% protein, is more than 1.00% but not more than 1.25% of the air-dry matter of the diet.

THE EFFECT OF AUREOMYCIN AND TYPE OF RATION ON FATTENING LAMBS. R. F. Elliott and S. A. Ellsworth, *Lederle Laboratories*.

Two trials have been conducted to compare the effect of 2 levels of aureomycin (10 and 20 mg./lb. of total ration added as an aureomycin feed supplement) on weight gains and feed efficiency of western feeder lambs. Average initial weights were 69 lbs. in trial 1 and 63 lbs. in trial 2. Three types of rations were used, namely; 80% roughage, 20% grain; 60% roughage, 40% grain; 40% roughage, 60 grain. Five lambs were used per group. The addition of 20 mg. of aureomycin per lb. of feed produced a significant increase in gains ($P<0.05$) on an 80:20 or a 60:40 ration, while with the addition of the same amount of aureomycin to a 40:60 ration a small reduction was observed. A highly significant increase ($P<0.01$) in weight gains was observed at all levels of aureomycin as the ratio of roughage to grain was reduced from 80:20 through 40:60 with one exception (40:60+20 mg. aureomycin). Average daily gains and T.D.N./lb. of gain obtained with different levels of aureomycin on the 3 types of rations during a 10-week period were: 80:20 control 0.17 (10.1); 80:20+10 mg., 0.20 (8.6); 80:20+20 mg., 0.26 (7.6); 60:40 control 0.26 (6.8); 60:40+10 mg., 0.22 (7.3); 60:40+20 mg., 0.33 (5.4); 40:60 control 0.33 (4.8); 40:60+10 mg., 0.33 (4.9); 40:60+20 mg., 0.24 (6.0).

ISOLATION OF HOLOCELLULOSE FROM VARIOUS FORAGES BY THE ACID CHLORITE METHOD. Ray E. Ely and L. A. Moore, *U.S.D.A.*

Holocellulose was isolated from 9 forage samples by acid chlorite treatment. One hour treatment gave holocellulose yields (corrected for ash and lignin content) ranging from 90 to 100 percent of the theoretical yields. From 8 to 47 percent of the apparent lignin and from 13 to 27 percent of the nitrogen was retained by the crude holocellulose isolated with a 3 hour acid chlorite treatment. Summation of the ash, protein, lignin, alcohol-benzene extracts, and holocellulose contents of the 9 forages accounted for an average of 99.9 percent of the dry matter when the holocellulose was isolated by using a one hour acid chlorite treatment. These preliminary results indicate that holocellulose preparations might be of considerable value for forage analyses particularly from the standpoint of including a greater portion of the forage dry matter than is determined

with the conventional proximate analysis. These results also indicate that this material warrants further chemical study, characterization, and correlation with feeding value.

VITAMIN B_{12} AND CHOLINE SYNTHESIS IN THE BABY PIG. Jay Firth, Marian James, Irene Chang, S. P. Mistry, and B. Connor Johnson, *University of Illinois.*

Fifteen 2 to 3 day old baby pigs were divided into 3 groups and fed an alpha protein synthetic milk ration in order to study the effect of B_{12} deficiency on choline synthesis and the effect of pseudo B_{12} deficiency. Ten deficient animals were further subjected to a choline deficiency but with methionine supplementation to 1.6% of the diet, a level previously shown to be adequate for choline synthesis in the presence of B_{12}. (Nesheim and Johnson Jour. Nutr. *41*: 1950, 1949). Five of the animals received, in addition, 0.1% dimethylaminoethanol. Studies of the blood revealed a gradual decrease in number and size of red cells and in reticulocytes while hemoglobin remained relatively constant. Glutathione levels in the blood were slightly lower in the deficient animals. Injecting 4 pigs with 50 gamma of B_{12}/kg. body weight gave marked reticulocyte responses. No differences in urinary choline were noted after B_{12} injection. Urine collected during the fifth week and assayed with Neurosporra crassa Cholineless gave a uniformly higher response for the group receiving the dimethylaminoethanol. Histological examination of the liver and kidneys revealed no evidence of fattly infiltration or of renal damage. It thus appears that vitamin B_{12} is not involved in *in vivo* transmethylation from methionine to form choline. Pesudo B_{12} proved to be inactive for the baby pig.

INFLUENCE OF ADDED CARBOHYDRATE (CERELOSE) ON NITROGEN METABOLISM OF STEERS. J. P. Fontenot, W. D. Gallup and A. B. Nelson, *Oklahoma Agricultural Experiment Station.*

A nitrogen balance study was conducted with four steer calves fed prairie hay and one and two pounds of 20-, one pound of 30-, and one pound of 40-per cent protein supplement. When the supplements were fed at the one pound level, nitrogen retention increased as the percentage of protein in the supplement increased from 20 to 40 percent. The retention was further increased when two pounds of the 20-percent protein supplement were fed. The data indicated a possible protein-sparing effect of carbohydrate. A second test was initiated to study the effect of different amounts of available carbohydrate on nitrogen metabolism. A series of four nitrogen balance trials were conducted with 12 steer calves fed a low-protein wintering ration alone and supplemented with increasing amounts of cerelose. The daily basal ration contained 6 lbs. prairie hay, 0.6 lb. cottonseed meal and added minerals (Ca, P, NaCl) and analyzed 8.4 percent protein. Cerelose was added at the rate of 350, 700, and 1050 gm. daily. These additions lowered the protein content of the rations to 7.5, 6.9, and 6.3 percent, respectively. Urinary nitrogen decreased and fecal nitrogen increased as the amount of supplementary cerelose increased from 0 to 1050 gm. Average daily nitrogen retention for the rations containing 0, 350, 700, and 1050 gm. cerelose was 6.4, 6.2, 4.9, and 3.9 gm., respectively. Average biological values for the crude protein were 80.4, 83.5, 85.8 and 86.5 percent, respectively. It appears that at this protein level additions of available carbohydrate to rations of this type increase the utilization of absorbed nitrogen but decrease the total amount of nitrogen retained.

TIME STUDIES OF RUMEN CHANGES DURING A 16-HOUR FAST. Gall, L. S., Huhtanen, C. N., Saunders, R. K., Bjerknes, C. A. and Davis, L. R., *National Dairy Research Laboratories.*

Rumen samples are obtained from cattle and sheep for studies of such factors as the rumen flora, environment and the end-products formed during digestion. These samples must be as representative as possible of the condition of the rumen in the animal studied. Since ration is known to exert a great influence on these factors, it is important to know how they are affected by the degree of digestion of the ration. This information would aid in determining the best time for sampling. Studies to determine this influence were made on two fistulated animals fed different proportions of the same hay and gain mixture by taking rumen samples at several time intervals during the 16-hour period after feeding the animals. Rumen fluid samples were tested for pH, Eh, titratable acidity, volume of sludge, optical density, aerobic bacterial counts, cellulose digestion in the miniature artificial rumen using alfalfa leaf meal and Solka-Floc, lactic acid values and in some instances determinations of methionine and B-vitamin contents of the rumen fluid. Both animals showed variation in all determinations at all time intervals. In general the greatest changes fell within the first few hours after eating. Most changes such as in acidity, pH, lactic acid, volume of sludge and optical density of the rumen fluid reflected changes in the breakdown of food.

RESPONSE OF THE PIG TO SOURCES OF UNIDENTIFIED FACTORS. D. I. Gard, S. W. Terrill, and D. E. Becker. *University of Illinois.*

Two experiments were conducted to study six possible sources of unidentified factors for growth of the weanling pig. Pigs raised by sows maintained on semi-purified diets during gestation and lactation were used. Semi-purified (fortified cornstarch—isolated soybean protein) diets equalized for protein were used in both tests. In each test the pigs were allotted into eight lots from litter outcome groups. In test I a grass juice concentrate, dried whey and dried brewers yeast were studied singly and in all possible combinations without antibiotic in the diet. All pigs were individually-fed *ad libitum* in wire bottomed cages. Although there were no differences in efficiency of feed utilization, pigs fed grass juice concentrate alone or with dried whey exhibited significantly greater rate of gain. A similar design was used in test II to study the response of the pig to dehydrated alfalfa meal, menhaden fish solubles and a streptomycin residue in the presence of an antibiotic mixture. All pigs were individually hand-fed on concrete floors. Menhaden fish solubles failed to influence rate of gain. Dehydrated alfalfa meal and a streptomycin residue separately and in combination with each other, as well as in combination with menhaden fish solubles, produced a significant decrease in the average daily gain. Furthermore the streptomycin residue significantly depressed the efficiency of feed utilization.

SOFT PHOSPHATE WITH COLLOIDAL CLAY IN RATIONS FOR GROWING AND FATTENING SWINE. J. L. Gobble and R. C. Miller. *The Pennsylvania State College.*

Two experiments have been completed and a third is in progress in a study to determine possible harmful effects of soft phosphate with colloidal clay when this material is substituted for dicalcium phosphate in either of two types of rations for growing and fattening pigs in dry lot. In a generally accepted type of ration which contains animal protein supplement, no harmful effects were

observed in pigs fed the soft phosphate with colloidal clay over periods of from 112 to 180 days. In an all plant ration containing 2 percent soft phosphate with colloidal clay, no harmful effects were observed except a non-significant tendency for a slower rate of gain as compared with pigs receiving an equivalent amount of supplemental phosphorus from dicalcium phosphate. However, in an experiment underway at the present time, repeating the work with the all plant rations, there is no difference in rate of gain after 10 weeks between lots of 8 pigs each fed 2 percent soft phosphate with colloidal clay as compared to pigs fed 1 percent dicalcium phosphate. The state of phosphorus nutrition in the pigs on the completed experiments was normal as measured by the inorganic phosphorus content of blood plasma and the calcium, phosphorus and total ash contents of the bones. No gross symptoms of fluorosis were observed in any of the pigs. The addition of cobalt, copper, manganese and iron to an all plant ration fed to growing and fattening pigs and containing soft phosphate with colloidal clay did not improve the rate of gain.

THE EFFECTS OF FEEDING VARIOUS LEVELS OF FLUORINE TO LAMBS AS MEASURED BY METABOLISM STUDIES, FEEDING TRIALS AND BONE AND OTHER TISSUE STORAGE. J. M. Griffith, L. J. Hardin, C. S. Hobbs, and Hamdy N. Kemp, *University of Tennessee.*

Seventy-two wether lambs were used to determine the effects of fluorine at twenty-eight day intervals over a period of 140 days. The lambs were divided into six lots (I–VI) of ten each and three lots (VII–IX) of four each. The first six lots received 0, 25, 50, 75, 100, and 200 p.p.m. fluorine added as sodium fluoride, respectively. Lots VII through IX received 100 p.p.m. fluorine added as sodium fluoride plus the following alleviators, .1% aluminum sulfate hydrate, .5% aluminum sulfate hydrate, and .1% aluminum chloride hydrate, respectively. The lambs were fed one pound of concentrate (80% ground yellow corn and 20% wheat bran) and one pound of chopped lespedeza hay per day. The alleviators and sodium fluoride were added to the concentrate mixture. There were no significant differences in the apparent digestibility of crude protein, crude fiber, ether extract and nitrogen free extract that could be attributed to the treatments of the various lots. In general as the level of fluorine in the rations increased the retained fluorine as measured by bone storage and balanced studies increased. The lambs fed rations containing 100 p.p.m. of added fluorine with alleviators included had less fluorine stored in their bones than lambs fed similar rations without the alleviators included. There were no significant differences in the fluorine content of liver, heart, kidney, lung, and spleen between lambs that could be attributed to differences in fluorine content of the various rations fed.

THE EFFECT OF FEEDING CONTENTRATES TO EWES DURING LATE PREGNANCY ON MILK YIELD OF EWES AND BIRTH WEIGHT AND GROWTH OF LAMBS. Paul Q. Guyer and A. J. Dyer, *University of Missouri.*

Two tests have been conducted to determine how the feeding of concentrates in late pregnancy affects early lamb production. Two uniform groups, 30 head each, of large, mature range ewes were utilized. Throughout gestation, both groups grazed winter pastures e.g., bluegrass in the first test, alta-fescue in the second, and received legume hay when weather prevented grazing. One group was fed, in addition, a concentrate mixture (two pounds per head daily) during the last two months of pregnancy. Each ewe in this group was started on feed 60 days prior to expected parturition. During lactation all ewes were fed concentrates at the same rate until pasture was available. The lambs were fed grain.

Milk yield of ewes for the first 9 weeks of lactation and birth weight and growth rate of lambs were determined. In the first test, the followng advantages obtained from feeding concentrates: ewes raising singles produced 14% and those raising twins 8% more milk; single lambs were 8% and twins 22% heavier at birth; single lambs gained 9% faster to 16 weeks of age. In the second test, there was no advantage to feeding concentrates to ewes in late pregnancy. Milk yield, birth weights and growth rates of lambs were essentially the same for both groups of ewes.

THE VALUE OF LOW LEVELS OF STILBESTROL IN THE RATIONS OF FATTENING LAMBS. W. H. Hale, C. D. Story, C. C. Culbertson and Wise Burroughs. *Iowa State College.*

Methods of administration and critical evaluation of levels of stilbestrol in lamb fattening trials have not been fully investigated. Three lamb fattening experiments involving oral administration of low levels of stilbestrol have been conducted at this station. The lambs in each experiment were individually fed a basal ration of clover hay, ground corn, molasses, urea and minerals. To this basal ration were added various levels of stilbestrol ranging from 0.5 to 12 micrograms per pound of ration fed. Results from two of these experiments which were conducted during the winter and spring months respectively showed that oral administration of either 1.5, 2.0 or 3.0 micrograms of stilbestrol per pound of ration increased weight gains and improved feed efficiency in treated lambs as compared to the controls. The response in weight gains to the addition of 1.5 and 2.0 micrograms of stilbestrol to the ration was equivalent to the increased weight gains noted in lambs receiving 15 mg. of implanted stilbestrol. Oral administration of 6, 8 or 12 micrograms of stilbestrol did not increase weight gains of treated lambs over the gains of control lambs. Comparison of carcass data from stilbestrol fed and stilbestrol implanted lambs indicated superior carcass quality in the stilbestrol fed lambs. In a third lamb fattening experiment conducted during the past summer no increased weight gains or improved feed efficiency was obtained when lambs were fed low levels of stilbestrol.

B-VITAMINS AND OTHER FACTORS STIMULATORY TO CELLULOSE DIGESTION BY WASHED SUSPENSIONS OF RUMEN MICROORGANISMS. Glen Hall, E. W. Cheng and Wise Burroughs, *Iowa State College.*

Artificial rumen studies in this laboratory have consistently demonstrated the presence of unidentified substances in different feedstuffs which stimulate cellulose digestion by rumen microorganisms. In an attempt to determine the active principle responsible for this stimulation a more critical artificial rumen technique was developed using washed suspensions of rumen microorganisms. Using this technique the presence of unidentified factors was studied as well as the influence of specific B-vitamins and other compounds present in natural feeds. Each of the B-vitamins was tested singly and in various combinations. The vitamins stimulating cellulose digestion were: vitamin B_{12}, biotin, p-aminobenzoic acid, pyridoxin, riboflavin and folic acid. Of the combinations of vitamins studied, vitamin B_{12} and biotin were the only vitamins in which the effect of one was synergistic to that of the other. A combination of these two vitamins was more stimulatory to cellulose digestion than any single vitamin or combination of vitamins tested. Very small amounts of ribose, L-sorbose, xylose, arabinose and rhamnose were found to be slightly stimulatory. Despite the stimulation noted by these various compounds, no combination of them was found which stimulated cellulose digestion as much as that obtained from yeast extract. This substance

apparently contains unidentified factors stimulatory to cellulose digestion in addition to the compounds tested.

MEASUREMENT OF TRUE DIGESTIBILITY OF CALCIUM IN FEEDS FOR CATTLE. Sam L. Hansard and C. L. Comar, *Tennessee Agricultural Experiment Station.*

True digestibility of calcium in cattle feeds can be calculated from conventional balance studies when the endogenous fecal calcium is known. The endogenous fecal calcium can be determined by simple methods based upon the use of radiocalcium. Endogenous values determined on more than 50 cattle of various ages range from 1 gm. of calcium per day for month old calves to 4–5 gm. for yearlings; aged animals had values of 8–9 gm/day. It was demonstrated that in animals raised under similar condition the endogenous fecal calcium was practically constant within the various age groups, and was also unaffected by temporary changes in current dietary calcium. This indicates that it is possible to determine true digestibility for the dietary calcium from the balance trial and the estimated endogenous value. If radiocalcium is used, then the endogenous value for the particular animal can be determined simultaneously with the chemical balance. It is emphasized that the dietary levels of calcium in tests of rations or supplements must approximate the normal dietary calcium intake.

Some true digestibility values were as follows: month old calves on milk, 92–98%; mature cattle on normal ration of grain and hay, 30–40%; aged cattle on a like ration, 20%.

THE EFFECT OF LIMITED FEEDING ON GROWTH AND REPRODUCTION OF GILTS. L. E. Hanson, E. F. Ferrin, and W. J. Aunan. *University of Minnesota.*

Sixteen pairs of littermate gilts were placed in two groups at an average weight of 120 pounds, on December 21, 1951. Both groups were fed the same feed mixtures. One group (normal) was self-fed until after breeding (April), and the other group was hand-fed (limited). After breeding, both groups were moved to excellent brome grass pastures and both groups were hand-fed, though the limited group was given less feed than the normal group. When penned for farrowing and for a week after farrowing, all gilts were fed according to need on an individual basis. During the last 7 weeks of the suckling period both groups were self-fed and their pigs were creep-fed. At farrowing, the normal gilts had an average weight of 429 lbs.; the limited gilts, 304 lbs. Each gilt in the normal group had consumed an average of 1632 lbs. of feed from the start of the experiment to farrowing; each of the limited gilts, 959 lbs. of feed. The normal gilts farrowed an average of 8.23 live pigs with an average birth weight of 2.85 lbs. The 56 day weight was 31.7 lbs. The limited gilts farrowed 7.0 live pigs, weighing 2.63 lbs. each, weaned 6.70 pigs at a 56 day weight of 27.5 lbs. During the suckling period (7 weeks on pasture) the limited fed gilts consumed 199 lbs. more feed per head than the normal gilts and gained 71 lbs. per head. The normal gilts gained 3 lbs. per head. All gilts were fed for about 3 weeks after their pigs were weaned. They were then marketed.

ANTIBIOTICS IN RATIONS FOR LAMBS. E. E. Hatfield and U. S. Garrigus, *University of Illinois.*

Fifty late spring lambs (averaging 23 pounds) and thirty western black-faced feeder lambs (averaging 62 pounds) were fed in dry lot in Trials I and II

respectively to determine the effects of aureomycin HCl supplement on feed efficiency, growth rate, and carcass grade. The level of supplementation in both trials was ten mg. of aureomycin HCl per pound of concentrate mixture. There were no differences in feed efficiency between the lambs in the control lot and those in the supplemented lot. The average daily gains of the lambs were 0.31 pound for the controls and 0.36 pound for the supplemented in Trial I and 0.37 pound for the controls and 0.41 pound for the supplemented in Trial II. The carcasses of the supplemented lambs graded higher in both trials. In Trial III one hundred eleven spring lambs are being fed in dry lot to determine the effects of different antibiotics on feed efficiency, growth rate, and carcass grade. Antibiotic supplementation is at the same level as in Trials I and II. After 70 days of feeding the average daily gains are: controls 0.47 pound, Aureomycin HCl supplemented 0.55 pound, Aurofac supplemented 0.53 pound, TM-5 supplemented 0.50 pound, P-2 supplemented 0.51, and Aurofac plus TM-5 plus P-2 supplemented 0.49 pound.

NEW METHODS IN DETERMINING SUBSTITUTION RATIOS FOR CORN AND SOYBEAN OILMEAL IN SWINE RATIONS. Earl O. Heady, Roger Woodworth, Damon Catron, Gordon C. Ashton, *Iowa State College.*

Three studies with 464 pigs were used to study optimum levels of protein feeding, both with and without aureomycin. The protein concentrate, soybean oilmeal was fortified with vitamins and minerals. From these data, production functions or regression equations of the general form G=f (C,S) were derived where G is gain per pig, C is corn in pounds per pig and S is soybean oilmeal in pounds per pig. Equations were then derived to show the rate at which soybean oilmeal substitutes for corn at different pig weights; all possible combinations of corn and soybean oilmeal to produce a given pig weight have been calculated. Soybean oilmeal substitutes at declining rates at any given weight. At a 60 pound pig weight, 1 pound of soybean oilmeal substitutes for 12.5, 4.3, 2.7, 1.9, 1.4 and 1.1 pounds of corn with rations containing 10, 12, 14, 16, 18 and 20 percent protein respectively. Substitution rates also decline with heavier weights. At 175 pounds, the substitution rates are 2.7, 1.9, and .7 for 10, 12, and 14 percent protein respectively. Aureomycin increases the rate at which the oilmeal substitutes for corn. The marginal substitution coefficients of soybean oilmeal, in a ration containing aureomycin, are $.557\frac{C}{S}$, $.185\frac{C}{S}$ and $.108\frac{C}{S}$ for 60, 110 and 175 pound pigs respectively. The cheapest gain for any weight is attained with the ration where the corn/soybean oilmeal substitution ratio is equal to the soybean oilmeal/corn price ratio. These quantities have been calculated for different levels of corn and soybean oilmeal. From the derived substitution ratios simple charts and mechanical devices have been constructed. These provide quick calculation of the combination of corn and soybean oilmeal (fortified) which will maximize profits.

VARIOUS EFFECTS OF HIGH LEVELS OF FLUORINE INGESTED AS SODIUM FLUORIDE ON PREGNANT BEEF HEIFERS. C. S. Hobbs, J. B. Pardue, M. C. Bell, J. L. West, R. P. Moorman and G. M. Merriman, *University of Tennessee.*

The effects of administering fluorine in the form of sodium fluoride in high level amounts were studied on fourteen bred Hereford heifers divided into seven

lots, in a dry lot feeding experiment over a period of 14 months. Sodium fluoride was added to the basal ration of ground yellow corn, cottonseed meal, and good quality mixed legume hay so that the parts per million of fluorine added were: 0, 100, 200, 300, 600, 900 and 1200. The sodium fluoride was added to the concentrate mixture or was given by capsule to obtain the desired level of fluorine feeding. Symptoms of acute fluorine intoxication of anorexia, loss of weight, stiffness, emaciation and muscular tremors developed in those animals receiving 6.5 mg. of fluorine/kg. of body weight (600 ppm.) and above. All heifers receiving 600, 900, and 1200 ppm. were sacrificed periodically throughout the experiment when they became too stiff and weak to rise. Autopsies were made and tissue samples were taken for pathological studies. Both heifers receiving 13.0 mg. fluorine/kg. body weight (1200 ppm.) developed clonic convulsions two days prior to being sacrificed and one of these heifers lost 273 pounds over a 35-day period. The remaining heifers, those receiving 5.7 mg. fluorine/kg. body weight (300 ppm.) and less, were sacrificed 422 days after the beginning of the experiment. Some abnormalities were noted in the lots receiving 200 and 300 ppm. of added fluorine. Control heifers weighed more and consumed slightly more feed than the heifers fed rations containing 100 ppm. on air-dry basis. Some of the calves from cows on the higher levels were small but there were no observed difficulties at parturition time.

VITAMIN B_{12} AND PSEUDO VITAMIN B_{12} IN THE NUTRITION OF THE CALF. John H. Hopper and B. Connor Johnson, *University of Illinois.*

Using a "synthetic milk" diet, a study was made of the utilization of pseudo vitamin B_{12} (i.e. the form of vitamin B_{12} containing adenine rather than dimethylbenzimidazole) by the young dairy calf. It has been shown that pseudo vitamin B_{12} is produced by rumen microorganisms. Thus, we felt that it would be of value to determine whether it could be used as a B_{12} source by the ruminant. Calves were maintained on a synthetic diet, (A. C. Wiese, B. Connor Johnson, H. H. Mitchell, and W. B. Nevens. Jour. Dairy Sci. 30:87, 1947) in which the protein source was Drackett soybean "protein 220". They were fed for a period of 17 weeks, during which vitamin B_{12} and pseudo B_{12} were given by intramuscular injection. A calf was made B_{12} deficient and then given pseudo B_{12} in an effort to correct the deficiency, 1 mg. being injected weekly for five weeks following the appearance of a B_{12} deficiency. This pseudo B_{12} calf lost an average of 2.1 lbs. in body weight per week during this period, as compared to 5.0 lbs. gain in body weight per week for a calf receiving crystalline B_{12}. Our data indicate that pseudo B_{12} cannot correct a B_{12} deficiency in the young dairy calf.

A STUDY OF THE EFFECTS OF ANTIBIOTICS UPON THE DIGESTION OF FEED NUTRIENTS BY YEARLING STEERS, WITH BACTERIOLOGICAL DATA. L. H. Horn, Jr., R. R. Snapp, and L. S. Gall, *University of Illinois.*

Two series of digestion and nitrogen-balance studies, using eleven steers fed two well balanced rations, were conducted. Four antibiotics and sulfathalidine powder were added separately and in combination to the rations to ascertain the effects upon the digestion of the feed nutrients and nitrogen retention by the steers. Basal digestion trials were conducted on one group of five and the other group of six steers before feeding them the drugs. It was found that aureomycin from Aurofac 2A (Lederle) (3.6 gm. of aureomycin and 1.8 mg. of vitamin B_{12} per pound of supplement) fed at the rate of 32 or 100 mg. per day caused a decrease in the digestibility of feed nutrients. Thirty-two, 100 or 400 mg. of

penicillin from Antibiotic Feed Supplement (Merck) (0.2 gm. of penicillin per gm. of supplement) had no effect on the digestibility of the nutrients. Both aureomycin and penicillin at all levels caused a highly significant (P=0.01) decrease in nitrogen-retention. Penicillin at the 100 mg. level did not appear to upset the rumen flora and environment. The steers fed 100 mg. of aureomycin supported a less desirable rumen flora and showed a decreased ability to digest fiber in the miniature artificial rumen. A mixture of 100 mg. of crystalline aureomycin, 100 mg. of streptomycin sulphate, 100 mg. of terramycin and 30 gm. of sulfathalidine powder fed on three consecutive days produced no apparent change in the steers.

EFFECT OF SURFACTANTS AND BENTONITE ON FATTENING LAMBS. R. M. Jordan, *South Dakota State College.*

Feeder lamb responses to surfactants (ethofat C^{15}) and sodium bentonite were studied. The lambs were fed as follows: Trial I, Lot I, shelled corn, alfalfa brome hay, and soybean meal; Lot II, same as Lot I with the exception that 3% ethofat C^{15} was added to the soybean meal. Trial II, Lots I and II fed as in trial I; Lot III was fed as Lot I but in addition received sodium bentonite which was added to the soybean meal (2 parts soybean meal and 1 part bentonite). This mixture was fed at a rate so as to provide equal protein intake in all three lots. In the first trial there was no difference in average daily rate of gain (Lot I .37 pound, Lot II .38 pound), average daily feed consumption and feed efficiency. In the second trial the average daily gain per lamb was .35, .35, and .38 pound in Lots I, II and III respectively. There was no difference in carcass grade or yield, feed consumption or feed efficiency between Lots I and II. Lambs in Lot III were somewhat easier to keep on feed, and required slightly less feed per 100 pounds of gain.

THE RESPONSE OF COBALT-DEFICIENT LAMBS TO ORALLY ADMINISTERED VITAMIN B_{12}. C. J. Kercher and S. E. Smith, *Cornell University.*

In this study the response of cobalt-deficient lambs to orally administered vitamin B_{12} was compared with injected vitamin B_{12}. Body weight, feed intake, and hemoglobin level were used as measurements of response. Prior to treatment the lambs were fed a cobalt-deficient ration until they showed definite signs of cobalt deficiency-anorexia, loss of weight, and anemia—which was approximately nine months. The feeding of 500 micrograms of crystalline vitamin B_{12} daily for five weeks (a total of 17.5 mg.) to cobalt-deficient lambs produced as favorable a response in appetite, body weight, and hemoglobin level as the injection of a total of 500 micrograms over a two week period. Assuming these responses to be approximately equal, about three percent of the orally administered vitamin must have been absorbed from the gastro-intestinal tract. The oral administration of 100 micrograms of vitamin B_{12} daily as a feeding supplement was also found to be effective in alleviating cobalt deficiency. However, cobalt analysis of the feeding supplement showed enough cobalt to give a response to cobalt *per se*. In another group of cobalt-deficient lambs, 100 micrograms of crystalline vitamin B_{12} given by mouth failed to elicit a response. Thus it has been demonstrated that cobalt-deficient lambs will recover when fed vitamin B_{12} but the effective dose is approximately 35 times as much as the parenteral dose.

THE INFLUENCE OF PORCINE GAMMA GLOBULINS AND ANTIBIOTIC PELLETS ON THE GROWTH AND SURVIVAL OF BABY PIGS. J. F. Lasley, L. F. Tribble, A. A. Case and E. J. Penrod, *Missiouri Agricultural Experiment Station.*

A total of 340 baby pigs were used in a study of the influence of intraperitoneal injections of 10 c.c. of porcine gamma globulins during the first 24 hours of life on growth and survival to 56 days. One-half of each litter was treated and the other one-half used as a control. Weaning weights in pounds and mortality in percent were as follows: controls—40.8 and 12.9, treated—40.6 and 12.4. The influence of antibiotic pellets on survival and growth rate of baby pigs to 56 days of age was studied in two experiments. In both experiments, one-half of the pigs in each litter were pelleted, and the remainder were used as controls. In the first experiment involving 142 pigs, those receiving bacitracin pellets at 2 days of age averaged 33.66 pounds at 56 days as compared to 31.50 pounds for litter mate controls. This difference was significant ($P<.01$), but there was no significant difference in mortality between the two groups of pigs. When bacitracin pellets were not implanted until the pigs were 2 weeks of age, they had no effect on weaning weights of the pigs. In the second experiment involving 232 pigs, one-half of which were implanted with bacitracin or penicillin-bacitracin pellets, the weaning weight in pounds and mortality rate in percent were as follows: controls 43.2 and 9.1, treated—42.4 and 10.9.

CANE SUGAR IN PIG STARTERS. C. J. Lewis, D. V. Catron, G. E. Combs, and G. C. Ashton, *Iowa State College.*

Three experiments involving over 370 baby pigs were conducted to study the effect of sugar in pig starters. With one exception, the pigs were removed from the sows at one week of age and were given a limited amount of liquid sow's milk replacer along with a basal starter varying only in sugar levels. Self-feeders were randomly re-arranged twice a week to prevent place preference. In the first experiment 12 starters containing 0 to 20% sugar were simultaneously offered in three forms: meal, pellets, and sugar-coated pellets. The pigs consistently selected a pellet containing 20% sugar on the inside. Consumption increased as sugar increased regardless of the form of the starter. The pigs preferred pelleted to meal form. In another phase of this experiment, five starters (meal containing 0 and 20% sugar, pellet containing 0 and 20% sugar and a 20% sugar-coated pellet) were individually tested. The inclusion of 20% sugar in either meal or pellets significantly improved feed efficiency. Pelleting alone also significantly improved feed efficiency. In the second experiment 4 starters containing 0,10,15,20% sugar were offered simultaneously. The consumption ratios were 4:1:3:14, respectively. To study the pig's preference as to placement of the sugar, 3 pelleted starters were offered that contained 20% sugar inside, 10% sugar inside plus 10% sugar-coated, and 20% sugar coated. The respective consumption ratios were 22:9:1. A similar test with litters nursing sows gave consumption ratios of 11:2:1. In a third experiment there was again an indication of improved gains and feed efficiency with inclusion of sugar.

STUDIES IN BABY PIG NUTRITION. H. G. Luther, Wm. Reynolds, G. Pendergrass, P. P. Appel, and J. McGinnis, *Chas. Pfizer & Co.*

Data are presented on the evaluation of factors influencing growth response of baby pigs on various practical and synthetic rations. Studies of amylase activity of pancreas of pigs, indicate a low level of starch utilization in the

young pig but a rapid increase for 1st four weeks. Some growth studies are reported which support these observations. Results are reported showing the practicability of dry feeding of baby pigs. Terramycin supplementation at a level of 50 gm. per ton of feed gave the optimum response in a test involving graded levels of antibitotic supplementation. Studies of terramycin supplementation in pig starters showed a comparable pattern, however the growth response ranging from 5 to 30% over the controls, was often observed at the later portions of the growing period of 5 to 8 weeks. Studies using synthetic and practical rations indicate the response of baby pigs to an unidentified growth factor found in certain fermentation fractions.

THE VALUE OF MOLASSES FOR INCREASING THE INTAKE OF HAY AND TOTAL NUTRIENTS BY DAIRY CATTLE. R. E. Mather, J. E. Brockett, Jr., and B. R. Poulton, *New Jersey Agricultural Experiment Station.*

A single reversal design with two experimental periods of four weeks each with twelve cows was used to determine the influence of 2 lb. molasses daily sprayed under pressure over the hay, on hay intake, total nutrient intake and milk production. Grain was reduced 1.4 lb. to equalize energy intake. The increase in hay intake on the molasses ration from 11.4 lb. to 12.8 lb., and the decrease in silage intake from 39.0 to 35.8 lb. were both highly significant, while the decrease in 4 percent milk production from 37.7 to 37.3 was not significant. There was an increase in the difference between control and molasses groups in both hay and silage during each period, indicating that the maximum effects of the molasses may not yet have been observed. The increase in hay intake was about equal to the decrease in silage on a hay-equivalent basis.

INFLUENCE OF HORMONE LEVELS IN THE BODY ON NUTRITIONAL REQUIREMENTS. Joseph Meites, *Michigan State College.*

Studies in this laboratory during the past few years have indicated that either a marked excess or deficiency of a particular hormone or hormones in the body may increase the need for certain dietary factors. Administration of large doses of estrogens, thyroid substances or cortisone aggravated pre-existent deficiencies of vit. B^{12} or thiamine, as evidenced by reduced growth, survival and earlier appearance of other deficiency symptoms. Growth and survival of adrenalectomized, thyroparathyroidectomized and thiouracil-treated animals were also decreased when deficient diets were fed. Supplementation of these diets with 5 to 10 times the normal requirements for vit. B^{12} or thiamine largely counteracted the deleterious effects produced by a hormonal imbalance. These data may have practical application because of the possibilities of an increase in the use of hormones for growth and fattening of farm animals, and also because spontaneous dysfunctions of endocrine glands may occur.

THE INFLUENCE OF HIGH SODIUM CHLORIDE INTAKES ON GAIN, EFFICIENCY OF FEED UTILIZATION, NITROGEN BALANCE AND FEED DIGESTIBILITY. J. H. Meyer, W. C. Weir and J. D. Smith, *University of California.*

In experiment I, 4 lots of 10 ewe lambs each were fed the following added NaCl levels (dry basis) 0, 5.2, 9.5 and 13.7%. The basal ration consisted of 85% alfalfa, 15% barley and 0.5% NaCl. All rations were pelleted. The average daily gain, basal ration intake, NaCl intake and basal ration per 100 pound gain for each of the 4 lots were 0.47, 0.52, 0.45 and 0.48 pounds; 4.14, 4.08, 3.77 and 3.88

pounds; 0, 91, 168 and 263 grams; and 884, 790, 842, and 812 pounds respectively. Blood hematocrit and serum albumin indicated no accumulation of extracellular fluid in any of the lots. The data do not indicate a detrimental effect from the high NaCl intake but indicated an increased feed utilization. Experiment II consisted of a metabolism trial using the above rations but compounded from different lots of feedstuffs. A 4x4 latin square design was used. The basal ration TDN, apparent nitrogen digestibility and nitrogen retained for each of the 4 lots were 56.7, 59.9, 57.0 and 57.5%; 74.0, 75.0, 72.8, and 75.7%; and 12.0, 21.3, 18.9, 31.2 grams respectively.

THE RIBOFLAVIN REQUIREMENT OF THE BABY PIG. E. R. Miller, R. L. Johnston, J. A. Hoefer, and R. W. Luecke, *Michigan State College.*

A total of 52 animals was used in three feeding trials to determine the riboflavin requirement of the baby pig. The first two experiments were designed to establish trends in the riboflavin requirement of the baby pig and to develop techniques for reducing experimental error. The third experiment gave significant evidence for establishment of a riboflavin requirement level. Following a depletion-adjustment period on a riboflavin free, synthetic milk diet, the pigs were placed on diets supplemented with five different levels of riboflavin, ranging from the basal no riboflavin level to 4.0 mg. per kilogram of solids. The feeding method was essentially *ad libitum*. Data on individual growth response and dietary intake were recorded. Analysis of the data indicate that the dietary riboflavin requirement of the baby pig for optimum growth is very near 3.0 mg. per kilogram of solids. External, gross and microscopic lesions were present only in those animals receiving less than 2.0 mg. of riboflavin per kilogram of solids. After the close of experimental feeding, the rate of growth and efficiency of feed utilization of the deficient animals were greatly improved by periodic intra peritoneal injection of riboflavin.

SOME DISCREPANCIES IN A.O.A.C. CRUDE FIBER AND N.F.E. VALUES IN ROUGHAGES. A. L. Moxon and O. G. Bentley, *Ohio Agricultural Experiment Station.*

The crude fiber content of several feeds has been determined by the A.O.A.C. method and by the Wilcox-Moxon method. Cellulose has also been determined on the original feeds and on fiber residues from the two methods for crude fiber. The A.O.A.C. crude fiber method is a fairly good measure of the cellulose content of feeds but a poor measure of the lignin and other fiber constituents. The residue from the A.O.A.C. method contains 70% to 93% cellulose (86.6% from oat hulls) and accounts for about 90% of the total cellulose. The Wilcox-Moxon method also accounts for about 90% of the cellulose in high fiber feeds but the residues contain only about 40% cellulose, thus allowing a place for lignin and other crude fiber constituents. The crude fiber content of oat hulls is only 38% by the A.O.A.C. method and is 82.38% by the Wilcox-Moxon method. In most feeds the difference between the fiber values by the two methods is largely accounted for by the lignin content. Thus the Wilcox-Moxon method gives a crude fiber value which represents the portion of feed undigested by the non-ruminant animal. The difference between the A.O.A.C. and the Wilcox-Moxon values should approximate the portion of the feed which is undigestible for ruminant animals except for those feeds such as corn cobs, which are high in pentosans. Use of the A.O.A.C. fiber method places most of the lignin in N.F.E.

IMPROVING A SWINE RATION CONTAINING ROUGHAGE AND UREA BY FERMENTING WITH RUMEN MICOORGANISMS. M. E. Muhrer, G. B. Garner and W. H. Pfander, *University of Missouri.*

These studies were conducted to determine whether a ruminant-type ration containing roughage and urea could be improved for nonruminants by fermentation in an artificial rumen. A ration containing 72.5% yellow corn, 15% alfalfa meal, 5% soybean oil meal, 2.5% urea, 2.5% molasses and 2.5% minerals was inoculated with rumen microorganisms and fermented at 38° C. for at least 24 hours before feeding to swine. Pigs, weighing about 60 lbs. each, that were fed the fermented ration gained 1.3 lbs. per day while control pigs on the untreated ration gained only 1.0 lbs. per day. The four pigs in each lot were pair fed for 70 days. In a second trial the ration was divided so that either a known part or all of the ration could be fermented. Pigs similar to those used in the first trial were divided into three lots of 4 each and pair fed for 56 days. Control pigs on the untreated feed gained 1.07 lbs. per day and required 520 lbs, of feed per 100 lbs. of gain. Pigs receiving the fermented ration gained 1.27 lbs. per day and required 437 lbs. of feed per 100 lbs. of gain. When only the alfalfa meal, urea, molasses and mineral portion of the ration was fermented the pigs gained 1.48 lbs. per day and required only 375 lbs. of feed per 100 lbs. of gain. This second trial was repeated using smaller pigs with similar results. These data indicate that a ration for nonruminants can be improved by fermenting some ingredients of the ration in an artificial rumen.

THE RELATIVE VALUE OF CAROTENE IN OIL SOLUTION AND IN ALFALFA MEAL AND OF THE VITAMIN A-ACTIVE CAROTENOIDS IN YELLOW CORN FOR SUPPLYING VITAMIN A FOR SWINE DURING GESTATION AND LACTATION. D. B. Parrish, C. E. Aubel and J. S. Hughes, *Kansas Agricultural Experiment Station.*

In trial 1 gilts were divided into 3 lots and given a basal carotenoid-low feed plus daily supplements of carotene in oil, 23,000 and 7,800 vitamin A units, or carotene in alfalfa meal, 7,800 units. In trial 2 the same supplements, 20,000, 6,500 and 6,500 units, respectively, were given. In trial 3, using two lots of gilts, 6,500 units of vitamin A as carotene in alfalfa or as vitamin A-active pigments in yellow corn were given. Cryptoxanthin of corn was calculated as having one-half the vitamin A potency of an equal amount of carotene. Supplementation was commenced an average of 4 weeks before the gilts were bred in the fall. As judged by concentrations of vitamin A in blood and colostrum of the gilts and in blood and livers of new-born pigs, the smaller amounts of carotene in oil were less effective than carotene of alfalfa, especially for liver storage. The larger amounts of carotene in oil were as a whole a little more effective than the smaller amounts of carotene from alfalfa. The vitamin A-active pigments of alfalfa and yellow corn were of similar value, although the data were variable when comparing different criteria of measurement.

BLOAT AND RUMEN MOTILITY AS AFFECTED BY FORAGE EXTRACTS AND OTHER RELATED SUBSTANCES. A. R. Parsons, C. K. Whitehair, and A. L. Neumann, *University of Illinois.*

Rumen contents from cows that died due to bloat inhibited the motility of the isolated rabbit intestine. This effect was also noted with forage extracts taken from the pastures these animals were grazing at the time of death. This inhibition was not observed when the rumen contents from normal cattle were

used. Considerable variation in the motility of the isolated rabbit gut was noted when a variety of legume and grass extracts as well as some selected chemical compounds were used. Acute bloat and death were produced in sheep using an extract of Ladino clover. A fistulated cow was used to study the effect of forage extract on rumen motility. Orally administered legume extracts were noted to inhibit the eructation mechanism.

THE EFFECT OF AUREOMYCIN ON THE GROWTH, FATTENING AND FEED UTILIZATION OF BEEF CATTLE. T. W. Perry, W. M. Beeson and E. C. Hornback, *Purdue University Agricultural Experiment Station.*

Suckling calves given an oral daily dose of 24 mg. aureomycin per 100 pounds body weight until each calf was eighty days of age grew more rapidly (1.78 lb. vs. 1.59 lb.) and showed less incidence and severity of scours than control calves not given aureomycin. Yearling steers and heifers receiving an average of 15 mg. aureomycin per pound of concentrate grew more rapidly (1.64 lb. vs. 1.52 lb. per day) and required 8.4 percent less feed per pound gain than control animals when a basal ration of corn, oats, soybean meal and free choice hay and minerals was fed over a twenty-six week period. Two lots of yearling steers were fed ground corn cobs and Purdue Cattle Supplement A, 3.5 lb., in which the consumption of the lot consuming the smaller amount of ground corn cobs controlled the other lot. Treated animals receiving this ration plus 75 mg. aureomycin per animal daily gained 43 pounds per steer more (151 lb. vs. 108 lb.) in the first 84 days of the trial. As the trial continued, this advantage was maintained but was not increased. A mixed group of calves and yearlings was fed ground corn cobs, free choice, and Purdue Cattle Supplement A, 3.5 lb. Treated animals receiving 75 mg. aureomycin per head daily gained 32 pounds more (127 lb. vs. 95 lb. per steer) than the control group for the first 56 days of the trial. In a fattening type ration, a level of 75 mg. aureomycin per steer daily exerted no effect on growth rate.

THE EFFECT OF SUPPLEMENTING PRACTICAL RATIONS FOR WEANLING PIGS WITH LYSINE AND METHIONINE. W. H. Pfander and L. F. Tribble, *University of Missouri.*

The effect of supplementing two practical swine rations (fortified with vitamins and minerals to meet the Recommended Allowances of N.R.C., and terramycin) with L-lysine hydrochloride and methionine on the rate and economy of gain of weanling pigs was studied. Using a Latin Square experimental design six litters of six Chester White pigs were allocated at weaning to six treatments (1—Basal A; 2—Basal A+0.15% L lysine; 3—As 2+.04% methionine; 4—Basal B; 5—Basal B+0.15% L lysine; 6—As 5+.04% methionine. Basal A contained corn, tankage, soybean oil meal, and shorts. Basal B contained corn and soybean oil meal). The mean daily gains and feed efficiencies of the pigs on the treatments from weaning to 100 lbs. were 1—1.29, 293; 2—1.39, 280; 3—1.29, 274; 4—1.34, 294; 5—1.24, 289; 6—1.36, 300. If effects of litter and sex are removed, the pigs on treatments 2 and 6 gained faster (P .05) than their controls (1 and 4), during the period weaning to 75 lbs. Pigs on treatment 2 gained faster than their controls (1) throughout the experiment. The corn and soybean meal ration was not improved by the addition of 0.15% L lysine even though it would appear to be deficient on the basis of present analyses and the recommendations of the N.R.C. The mixed protein basal ration was not greatly improved by the addition of lysine. The corn-soybean oil meal basal ration was improved by the addition of .04% methionine until the pigs weighed 75 pounds.

THE EFFECT OF ADDING TRACE MINERALS TO RATIONS OF IDENTICAL TWIN BEEF CATTLE. M. P. Plumlee, Robert Totusek and W. M. Beeson, *Purdue University*.

Two experiments were conducted with identical twin beef cattle to determine the value of trace mineral additions to a ration of ground corn cobs and Purdue Cattle Supplement A. In the first experiment two sets of twins weighing approximately 550 lbs. each were fed 3.28 lbs. of Supplement A per day plus corn cobs limited to the amount eaten by the twin with the least appetite. One twin of each set received daily the following trace minerals: Mg, 3.0 gms.; Mn, 130 mg.; Co, 1.0 mg.; Cu, 25 mg.; Fe, 130 mg.; and Zn, 1.0 mg. The average daily gains for the 112-day feeding period were 1.57 and 1.45 lbs. for the controls and 0.94 and 1.20 lbs., respectively, for the twins which received the trace minerals. In the second experiment the same basal ration was fed and practically the same system of feeding was followed as before. One individual of each of five sets of twins received the basal ration with no trace minerals; two calves received the basal ration plus all the trace minerals in the same amounts fed in the first experiment; and three twins each received the basal ration plus all the trace minerals except Mg; Mg and Fe; Mg, Fe and Mn, respectively. Feeding trace minerals depressed the appetite and therefore controlled the intake of cobs for the pair. Later in the experiment on *ad libitum* feeding the twins receiving trace minerals ate less cobs and grew at a slower rate. Further research will have to be conducted before the trace minerals or mineral element causing a depression of appetite can be determined.

AMINO ACID SUPPLEMENTATION TO CORN AND MILO RATIONS FOR GROWING PIGS. Wilson Pond, J. C. Hillier, and R. W. MacVicar, *Oklahoma Agricultural and Mechanical College*.

Three feeding trials were conducted to study the effects of supplementing low protein rations with methionine and/or lysine. Observations were also made on the utilization of the D-isomer of lysine for growth of swine. In Trials I and II, the addition of 0.10 percent DL-lysine to a 12 percent protein corn-soybean meal ration improved the growth rate and feed efficiency from weaning to 90 and 120 pounds, respectively. Improvement in growth rate and feed efficiency was significant in Trial I and approached significance in Trial II. The addition of higher levels of DL-lysine were progressively less effective in promoting growth and improving feed efficiency in both trials. In Trial II, a 16 percent protein ration was superior to the basal ration but approximately equal to the basal ration plus 0.10 percent DL-lysine in improving growth and economy of gain. In Trial III, supplementing a 14 percent protein milo-soybean meal ration with 0.10 percent L-lysine produced the most rapid gains, followed by identical rations supplemented with 0.05 percent L-lysine and 0.20 percent DL-lysine, respectively. Although no statistically significant differences in rate or economy of gain of pigs fed these rations were revealed the pigs fed the rations supplemented with L-lysine again tended to exceed those fed the unsupplemented ration in both respects. These trials suggest that lysine is a limiting amino acid in corn-soybean meal and milo-soybean meal rations containing 12–14 percent protein. The D-isomer of lysine may interfere with the usefulness of DL-lysine as a supplement to swine rations as indicated by an inverse response to added increments in excess of 0.10 percent.

EFFECT OF AUREOMYCIN AND/OR GRASS JUICE CONCENTRATE ON CELLULOSE DIGESTION IN AN ARTIFICIAL RUMEN, AS INFLUENCED BY DIFFERENT SOURCES OF NUTRIENTS. J. J. Radisson, E. E. Bartley, F. C. Fountaine and F. W. Atkeson, *Kansas State College.*

The effect of aureomycin on cellulose digestion was studied, using the artificial rumen technique described by Huhtanen and Gall. Ground filter paper or alfalfa hay were used as the main sources of cellulose. Various materials, including starch, a grain mix, grass juice concentrate and aureomycin were added either alone or in combinations. Rumen samples were obtained by stomach tube from young dairy calves fed alfalfa hay and a grain mix. Both alfalfa hay and grain, in moderate amounts, markedly increased the digestion of cellulose in filter paper, with or without aureomycin and/or grass juice added. The digestion of cellulose in alfalfa hay was also stimulated by grain but to a lesser extent. At the levels used, starch decreased cellulose digestion. Grass juice, with or without copper added, or the same product after autoclaving, depressed the digestion of cellulose in filter paper at most levels. When alfalfa hay was used, grass juice appeared slightly beneficial at low levels in the absence of aureomycin, whereas it was detrimental in the presence of aureomycin; at higher levels, grass juice was detrimental in all cases. Aureomycin markedly decreased the digestion of cellulose in filter paper, with or without starch, grain and/or grass juice added. In contrast, only a slight or no inhibition was observed when aureomycin was added to alfalfa hay, with or without the addition of starch, grain and/or grass juice. Present evidence indicates that there are factors in alfalfa hay, and to a lesser extent in grain, which prevent the depressing effect of aureomycin in cellulose digestion.

UNIDENTIFIED GROWTH FACTORS FOR SWINE. W. M. Reynolds, G. Pendergrass, P. P. Appel, H. G. Luther and J. McGinnis, *Chas. Pfizer & Co.*

Feeding tests with baby and growing and fattening pigs were conducted on practical and synthetic rations to determine the value of several substances possessing unidentified growth factor activity for chickens and turkeys. The sources of unidentified growth factor activity were fractions from various fermentation processes including terramycin, streptomycin and penicillin. These substances were evaluated against, and in combination with meat scraps and fish solubles. On the basis of several tests, the fractions possessing unidentified growth factor activity, supported an extra growth response on practical corn-soya ration of 10% in contrast with approximately 6–8% for meat scraps. In general, the growth response patterns obtained with swine and poultry are similar for these fractions tested.

PHYSICAL CONDITION, MOISTURE CONTENT AND GROWTH OF MOLDS AS FACTORS IN THE SPOILAGE OF ANIMAL FEEDS. L. R. Richardson and J. V. Halick, *Texas Agricultural Experiment Station.*

The moisture level (critical moisture level) at which various feedstuffs were safe from the growth of molds and heating was determined. Ground grains heated at lower moisture levels and to higher temperatures than whole, crimped or flaked grains. Wheat containing 14.1% moisture did not heat, while ground wheat with the same moisture content started to heat in 5 days and reached a maximum of 44° C. in 8 days. Ground wheat was safe when it contained less than 12.3% moisture. Preliminary tests with flaked wheat indicate that its critical moisture level will be between that for whole and ground wheat. Similar

differences were observed in ground, whole and flaked corn. The influence of molasses on heating varied. Molasses hastened heating when the moisture content of the ingredient was at a borderline level. Corn meal, which contained 12.3% moisture and was safe for 42 days, started to heat in 13 days when 10% of molasses containing either 22 or 27% moisture were added. Both mixtures reached a maximum of 46° C., but it took 30 days for the mixture containing molasses with 22% moisture to reach the maximum compared with 17 days for that containing molasses with 27% moisture. The addition of molasses to wheat bran containing 17% moisture delayed heating, and molasses low in moisture delayed heating longer than those high in moisture.

DIFFERENT LEVELS OF PROTEIN WITHOUT AND WITH AN ANTIBIOTIC OR A B_{12} AND ANTIBIOTIC SUPPLEMENT FOR PIGS. W. L. Robison, L. E. Kunkle, V. R. Cahill, and H. S. Teague, *Ohio Agricultural Experiment Station.*

In one trial aureomycin in soybean oil meal rations produced slightly faster gains and saved 17.2, 9.1, and 9.8 pounds of feed per 100 pounds of grain with low, standard, and high protein rations, respectively. Without or with aureomycin, low protein rations produced as rapid and as efficient gains as standard and high protein rations.

In a second trial with B vitamins, and without and with aureomycin, pigs on standard made more efficient gains than pigs on low protein rations. With neither added, a low produced as rapid and efficient gains as a standard protein ration. In a third trial with neither, pigs on low made as efficient but hardly as rapid gains as pigs on a standard protein ration. When a B vitamins concentrate or it and a B_{12} and antibiotic supplement was used, low produced as rapid and as efficient gains as standard protein rations. During the first six weeks of a fourth trial four groups of pigs on low made less rapid and less efficient gains than four groups on standard protein rations. Cobalt with the low and standard protein rations produced faster gains and reduced the feed required per unit of gain 4.8 and 7.0 percent, respectively. Adding a B vitamins concentrate and both it and a B_{12} and antibiotic supplement each increased the rapidity but not the efficiency of the gains. The low, standard, and high protein rations approximated 12.5, 15.5, and 18.5 percent before and 10.5, 13.5, and 16.5 percent of protein after the pigs weighed 120 pounds.

PEA SUPPLEMENTS, PELLETING, SELF-FEEDING, AND PEA VINE SILAGE IN LAMB FATTENING. B. H. Schneider, L. C. Luce, and E. E. Goodwin, *State College of Washington.*

Thirty-two groups of 6 lambs each were fattened in a replicated 2^4 factorial experiment to investigate the effects of: Austrian peas added to an adequate but low-protein ration; pelleted vs. unpelleted feed; alfalfa hay vs. pea vine silage; and self-feeding vs. hand feeding. The pelleted or unpelleted feed mixture, other than the alfalfa hay or pea vine silage, consisted of 25% alfalfa meal, 20% dried molasses beet pulp, 52% barley, and 3% molasses. The peas, when fed, were substituted at a 10% level in place of an equal amount of barley. The lambs fed alfalfa hay gained an average of .47 pounds daily, while those fed pea vine silage gained only .38 pounds per head daily. However, 9.0 pounds of the alfalfa hay ration in comparison with only 8.0 pounds of the pea vine ration (calculated to an equal dry matter basis) were required per pound of

gain. These differences were very significant ($P<.01$). The lots self-fed pelleted feed and those hand fed unpelleted feed gained .44 and .45 pounds per head daily, while the lots hand fed pelleted feed and self-fed unpelleted feed gained .41 and .40 pounds per head daily, respectively. This interaction indicated significantly ($P<.05$) greater gains when pelleted feed was self-fed and just the opposite, i.e., greater gains with unpelleted feed when the lambs were hand fed. None of the other comparisons (individual treatments or their combinations) was significant. There were no death losses. The lamb carcasses graded 18 prime, 168 choice, and 6 good.

PENICILLIN FEEDING FOR PROPHYLAXIS OF SWINE ERYSIPELAS. B. H. Schneider, G. R. Spencer, and M. E. Ensminger, *State College of Washington.*

A replicated 2 x 2 factorial experiment was set up with 8 lots of 5 weanling pigs each to investigate the effects of erysipelas infection with and without penicillin feeding. They were all fed a ration consisting of barley, peas, fish meal, alfalfa meal, iodized salt, bone meal, and ground limestone. Two lots of isolated and two unisolated received dibenzylethylenediamine penicillin G (assay 1200 ug./mg.) at the rate of 80 gm. per ton of feed. The pigs to be infected were challenged by the dermal scratch method on the 25th day. Temperatures exceeded 106° F. for 3 days. The areas of the scratches became red, swollen, and firm. The pigs showed lassitude, anorexia, and slight stiffness. The growth curve was slightly flattened for about 2 weeks. No deaths occurred. At market weight the average daily gain of the erysipelas-infected pigs was 1.51 pounds, while the uninfected pigs gained 1.56 pounds daily per pig. The infected pigs required 389 and the uninfected pigs 400 pounds of feed per 100 pounds of gain. Neither of these differences was statistically significant. The penicillin-fed pigs gained an average of 1.62 while the others gained only 1.52 pounds per head daily. The pounds of feed per 100 pounds of gain for penicillin and non-penicillin-fed pigs were 381 and 409, respectively. These differences were significant ($P<.05$) in favor of penicillin feeding both in rate of gain and in feed efficiency. On slaughter there were no lesions attributable to the erysipelas infection.

THE VALUE OF SURFACTANTS IN RATIONS FOR GROWING-FATTENING PIGS. B. E. Sheffy, A. J. Clawson and J. P. Willman, *Cornell University.*

Two experiments consisting of eight lots each, with a total of 136 pigs (2 cubed factorial) were conducted to test the value of various surfactants and the antibiotic aureomycin, when added to a well-balanced animal and plant protein ration for growing-fattening pigs. The average daily gains for the various treatments are: First replicate; anionic 1.28, cationic 1.18, nonionic 1.21, aurofac 1.41, an-cat-aurofac 1.37, an-non-aurofac 1.30, cat-non-aurofac 1.37, an-cat-non 1.28. Second replicate; basal 1.28, an-aurofac 1.33, cat-aurofac 1.45, non-aurofac 1.52, an-cat 1.46, an-non 1.28, cat-non 1.33, an-cat-non-aurofac 1.46. The increased daily gains resulting from the addition of aureomycin were highly significant. There was a significant interaction between aureomycin and the anionic surfactant. There was no beneficial response from the additions of any of the surfactants alone. The feed intake of the aureomycin supplemented lots was increased over those not receiving aureomycin. The amount of feed required to produce 100 lbs. of gain was not significantly different between antibiotic and non-antibiotic supplemented lots.

"COTTONSEED MEAL IN PRACTICAL RATIONS FOR GROWING AND FATTENING SWINE." C. B. Singletary, A. B. Watts, R. M. Crown and R. A. Damon, Jr., *Louisiana Agricultural Experiment Station.*

The purpose of this study was to evaluate the quality of protein in cottonseed meal, as affected by different methods of manufacture, when fed singularly and in combination with solvent extracted soybean oil meal. The rations used were practical swine rations in which cottonseed meal replaced soybean oil meal on an equivalent protein basis. Fifty-six purebred Duroc pigs with an average initial weight of 72 pounds were allotted equally into 7 dry lots on the basis of sex and weight. The pigs were grown to a weight of 200 pounds, at which time they were slaughtered and carcass information obtained. The rate of daily gains ranged from 1.87 pounds to 2.04 pounds for the various groups, and the covariance method of analysis showed no significant differences in rates of daily gains. The efficiency of feed utilization ranged from 336.9 pounds to 351.2 pounds of feed per 100 pounds gain among the seven lots. There did not appear to be any significant differences. There were no significant differences in average back fat thickness and yield of primal cuts among lots. Highly significant differences were found among lots in iodine numbers; however, all indicated hard fat. Employing the average back fat thickness as a determining factor for carcass grade, 62 percent were Choice No. 1, 31 percent Choice No. 2, 3.5 percent Choice No. 3, and 3.5 percent Medium. These studies indicate that 100 percent of our standard vegetable protein supplements can be replaced by low free-gossypol cottonseed meals with satisfactory results.

EXPERIMENTAL PRODUCTION OF FROTHY BLOAT IN CATTLE. C. K. Smith, J. R. Brunner, C. F. Huffman and C. W. Duncan, *Michigan State College.*

A ration consisting of corn, soybean oil meal, dicalcium phosphate, sodium chloride, calcium carbonate, vitamins A and D, and alfalfa brome hay produced frothy bloat in fistulated and intact dairy cattle. The bloat varied from mild to severe on different days. Severe bloat was evidenced by distress of the animal and refusal of the feed. The severe cases usually occurred before feeding in the morning. Methyl silicone and lipase treated cream were effective in reducing the froth. The appearance of an iodophilic streptococci is concurrent with the frothing.

USE OF A SPECIAL PROCESSED SOYBEAN FLOUR IN MILK REPLACEMENTS FOR YOUNG DAIRY CALVES. J. F. Stein, C. B. Knodt and E. B. Ross, *Pennsylvania Agricultural Experiment Station.*

A series of experiments has been conducted to evaluate the use of a special processed soybean flour in milk replacements for dairy calves. Because of cost or supply problems, it became necessary to find a substitute for some of the ingredients used in formulas previously published (Jour. Dairy Sci., 35:910, 1952). On the basis of the data obtained it appears that a replacement containing 35 percent soybean flour when supplemented with dried brewers yeast and whey solubles can replace dried whey, distillers dried corn solubles, blood meal and 10% of dried skimmilk in present formulas. The following milk replacement formula has given growth rates of 1.23 lb./day body weight gain to 49th day of age: dried skimmilk—38.50; whey solubles—5; oat flour—5; dextrose—7; dried brewers yeast—5; Di-calcium phosphate—2.5; Aurofac D (5 g. aureomycin

per lb.)—1; soybean flour—35; trace minerals—0.5; vitamin A & D_2 supplement (4000 U.S.P. units A and 500 U.S.P. units D_2 per gram)—0.5.

EFFICIENCY OF UREA UTILIZATION AS INFLUENCED BY MINERAL CONSTITUENTS IN A WINTERING RATION FOR BEEF STEERS. O. O. Thomas, D. C. Clanton and F. S. Willson, *Montana State College.*

The effect of adding phosphorus or trace minerals—cobalt, copper and manganese—to a wintering ration containing either urea or soybean meal was the subject of an experiment utilizing a factorial design. Added to a basal ration of barley, dried molasses beet pulp, vitamin A supplement, and mixed native hay containing a low amount of phosphorus were the following: Urea to Rations 1, 2, 3, and 4; soybean meal to rations 5, 6, 7, and 8; monosodium phosphate to Rations 3, 4, 7, and 8; and trace minerals to Rations 2, 4, 6, and 8. Fifty-six weanling Hereford steers averaging 390 lbs. were used as experimental animals, seven being assigned to each of the eight rations. Each of the eight rations was individually fed to steers in each of seven pens, two of which were located five miles from Bozeman. The average daily gains of the steers fed each ration during the 168-day winter feeding period were as follows: Ration 1, 0.61 lbs.; 2, 0.65 lbs.; 3, 0.97 lbs.; 4, 1.10 lbs.; 5, 0.82 lbs.; 6, 0.82 lbs.; 7, 1.19 lbs.; and 8, 1.03 lbs. Steers fed rations supplemented with soybean meal made significantly greater gains ($P \leq .01$) when compared with steers fed rations supplemented with urea. However, there was no significant difference between gains made by steers fed Ration 4 (urea, trace minerals, and adequate phosphorus) and gains made by steers fed Ration 7 (soybean meal and adequate phosphorus). Steers fed rations adequate in phosphorus made significantly greater gains when compared to steers fed rations low in phosphorus. There was a highly significant difference in gains by steers fed at the two locations.

VALUE OF PELLETED RATIONS FOR SWINE. O. O. Thomas and A. E. Flower, *Montana State College.*

Two experiments were conducted to study the value of pelleting rations for fattening swine; pigs used in both experiments were crossbred from the Montana No. 1 and Duroc breeds. In the 1951 trial, 180 pigs averaging 27 lbs. were divided into two lots; one lot was self-fed the ration in a pelleted form, whereas the other lot was self-fed the same ration in a meal form. The pigs fed the pelleted rations required an average of 52 lbs. less feed per cwt. gain, gained 0.11 lbs. more per day, and reached market weight 12 days sooner than pigs fed the same ration in a meal form. In the 1952 trial, 48 pigs were divided into six lots on the basis of weight and sex. The initial average weights of pigs in the two heaviest lots was 50 lbs.; medium weight lots, 39 lbs.; and light weight lots, 31 lbs. The ration consisted of barley, oats, wheat mixed feed, dehydrated alfalfa meal, soybean meal, meat meal, complete mineral mixture, irradiated yeast, a B-vitamin supplement, and a B_{12} and antibiotic supplement. The pigs were weighed off the experiment at approximately 215 lbs. There was a significantly greater ($P \leq 0.05$) average daily gain among pellet-fed pigs than among meal-fed pigs (1.88 lbs. as compared with 1.62 lbs.). The average amount of feed required per cwt. gain was 345 lbs. for the pellet-fed lots and 413 for the meal-fed lots. The feed cost per cwt. gain was $12.44 for the pigs fed pellets and $14.46 for pigs fed the meal. Pigs fed the pelleted ration reached market weight 14 days sooner than did pigs fed the meal ration.

A CONTRIBUTION TO THE SEARCH FOR UNRECOGNIZED NUTRIENTS. L. F. Tribble and A. G. Hogan, *University of Missouri.*

Two gilts, farrowed by a sow on a synthetic diet, were continued on a similar ration, with alpha protein as the source of nitrogen. Each sow weaned a litter of 5 pigs with average weights of approximately 25 lbs. One sow was rebred for a second litter and farrowed 12 live pigs, but all were dead within 36 hours. Two gilts from her first litter were continued on the same type of diet until eight months of age when one of them was placed on a diet that contained casein. The number of pigs farrowed, number weaned and average 56 day weights were as follows: Litter A-7, 5, 29; Litter B-8, 6, 27. In another investigation soybean meal, casein and liver protein were compared as sources of protein for weanling pigs that consumed synthetic diets. The pigs were farrowed on concrete by sows that received a corn-soybean oil meal ration supplemented with crystalline B vitamins. The lots, treatments, average daily gain and feed efficiency were as follows: (1) soybean meal 1.15, 277; (2) casein 1.35, 236; (3) liver 1.18, 265; (4) soybean meal and casein 1.25, 265; (5) soybean meal and liver 1.18, 269; (6) casein and liver 1.23, 257; (7) casein and liver plus aureomycin 1.26, 252; (8) soybean meal plus aureomycin 1.18, 270. There is no reason to suppose that the most rapidly gaining pigs received a vitamin or other nutrient that has not been recognized.

SUPPLEMENTING CORN SILAGE FOR FATTENING STEERS. W. J. Van Arsdell, J. A. Hoefer, G. A. Branaman, R. W. Luecke, *Michigan State College.*

Thirty-two steers were divided into four lots of eight steers each. The steers were allotted on the basis of weight and grade. The corn silage was hand fed twice daily according to the appetite of the steers. Lots 1, 2, and 3 received 3½ lbs. of supplement per head per day while the steers in lot 4 received 3.82 lbs. One half of the daily supplement was mixed thoroughly with the silage at each feeding. The supplements were approximately equal in energy content and the crude protein content for lots 1, 3, and 4 was also approximately the same. Lot 1 steers (supplement contained soybean meal—2¼ lbs., molasses feed—1 lb., bone meal, trace mineral salt, and Vitamin A and D concentrate) gained an average of 2.33 lbs. per day over a 146 day feeding period. Lot 2 gained an average of 2.18 lbs. per day (soybean meal—3¼ lbs. plus minerals); lot 3, 2.07 lbs. per day (corn—3¼ lbs., urea—0.32 lb., plus minerals). Each of the supplements fed with corn silage proved to be satisfactory. The corn-urea supplement proved to be very efficient as a supplement to corn silage for beef cattle. There was little difference between the two quantities of soybean oil meal fed and the complex supplement containing molasses feed and vitamins.

THE EFFECT OF ANTIBIOTICS AND B-VITAMINS ON THE GROWTH OF PIGS FED DIFFERENT LEVELS OF PROTEIN. Richard C. Wahlstrom, *South Dakota State College.*

Two experiments were conducted to determine the value of supplementing a corn-soybean meal-tankage ration of varying protein content with B-vitamins and/or an antibiotic. In the first trial an 18% and a 14% protein basal ration was supplemented with 5 B-vitamins (riboflavin, calcium pantothenate, niacin, vitamin B_{12} and choline) and penicillin. The protein content was reduced two percentage units to 16 and 12 percent respectively when the pigs reached an approximate average weight of 130 pounds. The treatments, their respective daily gain and feed requirement per 100 pounds of gain were: (1) 18–16% protein

basal, 1.17, 384; (2) 18–16% basal + B-vitamins and penicillin, 1.67, 348; (3) 14–12% protein basal, 1.07, 404; (4) 14–12% protein basal + B-vitamins and penicillin, 1.70, 339. The second experiment was designed to determine whether the 5 B-vitamins or the penicillin was responsible for the improved growth rate of these rations. Twenty-four lots of 4 Duroc pigs each received an 18, 16, or 14% protein ration from weaning to 100 pounds at which time the protein content was reduced to 14, 12, and 10% respectively. On each protein level two lots of pigs received the basal ration alone, two received the supplement of 5 B-vitamins, two received penicillin and two received the 5 B-vitamins plus penicillin. The results at the end of the first eight weeks indicate little difference in rate of gain between protein levels; however, B-vitamin and penicillin supplementation produced improved gains of a similar magnitude while the combination of these supplements improved gains to the greatest extent.

THE EFFECT OF AUREOMYCIN ON THE GROWTH OF PIGS FED LIMITED RATIONS. H. D. Wallace, John McKigney, A. M. Pearson, and T. J. Cunha, *Florida Agricultural Experiment Station.*

Purebred Duroc and Duroc x Hampshire weanling pigs were divided into 7 experimental groups. Four pigs were fed in each lot and the experiment involved one replication. All pigs were hand fed once daily in four-hole self-feeders. They were maintained in concrete pens which were washed daily. The basal ration consisted of 78 parts corn, 15 parts soybean oil meal, 5 parts alfalfa leaf meal, 1 part limestone, 0.5 parts steamed bonemeal and 0.53 parts salt-trace minerals. The ration was fortified with thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, choline, folic acid and B_{12}. The feeding procedure for the seven lots was as follows: Lot I—Basal ration full fed; Lot II—Basal ration + 20 gm. of aureomycin per ton (intake regulated to that of Lot I); Lot III—Basal + aureomycin full fed; Lot IV—Basal fed at 80% of Lot I; Lot V—Basal + aureomycin fed at 80% of Lot I; Lot VI—Basal fed at 60% of Lot I; Lot VII—Basal + aureomycin fed at 60% of Lot I. Average daily gains for Lots I through VII, respectively, were 1.34, 1.38, 1.56, 1.15, 1.12, .81 and .86 after eleven weeks of the experiment. The first three lots were duplicated on pasture and gains after eleven weeks were 1.23, 1.30 and 1.35 respectively.

THE PHYSIOLOGY AND NUTRITION OF A RUMEN LACTOBACILLUS. R. H. Wasserman, H. W. Seeley and J. K. Loosli, *Cornell University.*

A number of anaerobic bacteria were isolated from rumen contents of mature ruminants on a urea-molasses supplemented ration. The medium employed in this study was relatively simple in composition, containing yeast extract, glucose, ammonium chloride, cysteine, phosphate buffer and salts. Isolates from dilutions of 10^{-7} or greater dilutions were purified and their physiology and nutritional requirements examined. Many were shown to be gram positive, catalase negative, homolactic, non-motile rods. Optically inactive lactic acid was formed during growth and lactose was fermented. The optimum temperature for growth was near 37° C. These characteristics and additional biochemical data indicated these bacteria to be variants of the species, *Lactobacillus bifidus*, differing from the type species by certain significant characteristics. The majority of the cultures tested required or were stimulated by thiamine, nicotinic acid, calcium pantothenate and biotin. Some of the isolates required or were stimulated by adenine, xanthine, guanine, uracil, riboflavin, pyridoxine, folic acid p-aminobenzoic acid, and B_{12}. No culture required choline or inositol. The

ability of *L. bifidus* variant from the rumen to utilize ammonia-nitrogen for growth was demonstrated. In the presence of cysteine, up to 60% ammonia-nitrogen in the medium was converted to bacterial nitrogen. Cystine, methionine, sodium thioglycolate and sodium sulfide could replace cysteine as a source of sulfur. The relative simplicity of the nutritional requirements of the isolates and their occurrence in the rumens of animals receiving non-protein nitrogen and soluble carbohydrates may indicate that they are important converters of non-protein nitrogen to protein nitrogen in the ruminant.

THE SULFUR REQUIREMENTS OF MATURE RANGE EWES. F. Whiting, S. B. Slen, L. M. Bezeau, and R. D. Clark, *Lethbridge Experimental Station.*

Six lots of 16 mature range ewes were fed, individually, pelleted rations in which the total sulfur content varied as follows: Lot 1, 0.084%; Lot 2, 0.128%; Lot 3, 0.171%; Lot 4, 0.128%; Lot 5, 0.170%; and Lot 6, 0.129%. The additional sulfur was added to Lots 2 and 3 in the form of inorganic sulfates, to Lots 4 and 5 in the form of elemental sulfur and to Lot 6 in the form of methionine. There were no significant differences between the 6 lots over a 9-month period in the body gain of the ewes in the quantity or quality of wool produced, in the weight or number of lambs produced, in the gain of the lambs to 6 weeks of age, in the total and inorganic sulfur content of the blood serum, in the total sulfur content of the colostrum, 7-day and 28-day milk, or in the sulfur content of the wool. The data indicate the sulfur requirements of the mature ewe for wool and lamb production does not exceed approximately 0.1% of the total ration.

EFFECTS OF SUBSTITUTING XYLOSE FOR GLUCOSE IN A PURIFIED DIET FOR PIGS. Milton B. Wise, E. R. Barrick, G. H. Wise, and J. C. Osborne, *North Carolina State College.*

In a previous investigation of the comparative growth responses of pigs fed diets containing 37.4% of either xylose or glucose or a 50–50 mixture of the two, the weight gains of the pigs fed glucose were approximately 4.5 times greater than those receiving xylose and 2.5 times greater than those receiving the mixture. Additional investigations, employing the equalized paired feeding technique, were conducted to ascertain factors contributing to the observed differences in growth performance. Five pairs of pigs were fed a "synthetic milk" containing 56% of either xylose or glucose, the only sources of carbohydrates, 4 times daily for a period of 49 days. The mean weekly gain in pounds/pig and pounds of feed/pound gain were, respectively: glucose diet, 1.64, 1.48; xylose diet, 0.96, 2.53. Means of nitrogen retention and of sugar recovery per pig for a 7-day period were, respectively; glucose diet, 19.8 gm., 0.6%; xylose diet, 7.4 gm., 50.0%. Sugar tolerance curves indicated that these differences were not due to differences in absorption of the sugars. Abnormalities noted in the xylose-fed pigs included mild glomerulo nephritis, hemorrhage in the Loops of Henle and cloudy swelling in the parenchyma of the kidneys; cataract formation in the lenses of the eyes; decreased voluntary activity of the animals, and a fading of the hair coat from a deep red to a yellowish red. No pathological lesions were detected in the glucose-fed pigs.

Pasture, Forage and Range Section

J. T. Reid, *Chairman*

EFFECTS OF VARIOUS TREATMENTS ON SOME COMPONENTS OF LEGUME-GRASS SILAGE. R. S. Allen and N. L. Jacobson, *Iowa State College.*

One-gallon glass jars were employed as miniature laboratory silos for comparing silages preserved with sodium nitrite, calcium acetate and dried beet pulp, respectively, with silage to which no preservative was added. Samples of freshly-cut legume-grass forage (largely clover) were mixed with the appropriate preservatives and were packed into the jars which then were sealed with screw-cap lids and paraffin. Each treatment was replicated 8 times and the bottles were stored at 75–80° F. Samples were taken at the time of ensiling and at 1, 4, 7, 14, 21, 28, 56 and 84 days thereafter. Analyses included moisture, total nitrogen, carotene, acetic and butyric acids, total water-soluble acidity, linoleic and linolenic acids, total "long chain" fatty acids and pH. With each treatment the carotene values decreased markedly after one or four days of storage. Subsequently, except for the sodium nitrite silage, there was a tendency for the carotene (separated chromatographically) to increase to values equal to or greater than the original. Whether the apparent increase was due to carotene synthesis has not been clearly demonstrated but an absorption spectrum of the "carotene fraction" did not differ perceptibly from that of beta-carotene. There was a slight increase in the linoleic and linolenic acid contents (dry matter basis) during the storage period. Acetic acid was the principal volatile fatty acid but paper chromatography also demonstrated traces of propionic acid in some samples. The greatest change in pH occurred within the first week. Sodium nitrite produced a silage of low quality, whereas beet pulp and calcium acetate gave results comparable to silage prepared with no added preservative.

PORTABLE UNITS FOR INDIVIDUAL EXPERIMENTAL PIG FEEDING PASTURE. G. C. Ashton, D. V. Catron, P. G. Homeyer, N. H. Curry and C. C. Culbertson, *Iowa State College.*

Swine pasture experiments are seldom replicated because of costly fencing, buildings and equipment; complexity of supplemental feeding and watering; large areas required for rotation of experimental lots to aid in disease control; cost of micro-nutrients needed for several lots of many animals per treatment; and failure to take into account the pasture-lot to pasture-lot variability. This paper presents a partial economic solution to the management, engineering, nutritional and statistical phases of the problem. A 3-compartment combination shelter-pen unit was designed 16 feet square complete with individual outside filled self-feeders, automatic waterers and a 30 gallon water reservoir. The use of plywood, aluminum, glued framework and special fasteners kept the total weight of the unit light enough for a 2-plow tractor to move it easily. Total cost per 3-pen unit approximates $550.00. The flexibility of the use of these units permits ready testing of multiple supplemental rations on a single type of pasture or on different pasture swards. With less efficiency the units may be used to measure the nutritive value of different pasture swards with a single supplemental ration. Individually fed animals usually provide for the maximum information and precision for the number of animals involved. The number of units available determines in part the type of experimental design which may

be used and the number of rations which may be tested efficiently. A set of 12 units (36 pigs) permits the use of completely randomized, randomized blocks, split-plot, Latin square, and incomplete block designs, and permits adequate testing of from 3 to 6 ration treatments per experiment depending on the nature of the rations and the design employed.

HAY CROP SILAGE AND HAY ALONE OR IN COMBINATION WITH CORN SILAGE OR HAY SILAGE FOR PREGNANT EWES DURING GESTATION. L. H. Blakeslee, H. A. Henneman, and R. H. Nelson, *Michigan State College*.

Two tests have been completed to show the proper method of using hay silage and its comparative value when roughages only are fed before lambing time. Five lots of 13 western ewes in 1952 and 12 western ewes in 1953 were fed the following average amounts of roughages, with free access to a 50% salt, 50% dicalcium phosphate mixture. Lot I Hay 4 lbs., Lot II Hay silage 10 lbs., Lot III Hay 1.35 lbs., Corn silage 4.25 lbs., Lot IV Hay silage 5 lbs., Corn silage 4.15 lbs., Lot V Hay 1.8 lbs., Hay silage 4.9 lbs. The gains per ewe from December 11, 1951 to March 28, 1952 were: Lot I 23.1 lbs., Lot II 25.2 lbs., Lot III 26 lbs., Lot IV 25.6 lbs., Lot V 20.6 lbs. From December 18, 1952 to March 24, 1953, the gains per ewe were, Lot I 15.5 lbs., Lot II 5.9 lbs., Lot III 18.1 lbs., Lot IV 19.8 lbs., Lot V 15.1 lbs. The first year, hay and hay silage were made from a similar Brome Alfalfa crop, but not from alternate windrows as was true with the Alfalfa mixture used the second year. Lamb and ewe weights and gains indicate: 1. Wilted good quality hay silage can be used as the only feed before lambing; 2. Comparable hay, alone or with silage produced as good or better results than hay silage; 3. Ewes like and usually do better on a mixture of good roughages than on hay silage only; 4. Use of silages only requires more bedding to keep the pens dry and clean.

THE INFLUENCE OF CERTAIN FACTORS UPON THE DIGESTIBILITY AND INTAKE OF PASTURE HERBAGE BY BEEF CATTLE. W. F. Brannon, J. T. Reid and J. I. Miller, *Cornell University*.

The digestibility and intake of herbage by 6 yearling steers grazing a permanent pasture were measured during the period of mid-June to late September. Two steers received a full feed of corn twice daily and two steers were full fed cane molasses in two meals per day in addition to the pasture herbage. By using the chromogen and Cr_2O_3 indicators, digestibility and intake of dry matter were estimated for 8 consecutive periods, the length of which was determined by climatic factors and the availability of aftermath herbage. Intake measurements derived from the chromogen-Cr_2O_3 method compared favorably with those derived from total collections of feces regardless of whether or not supplements were fed. The digestibility (%) of the herbage dry matter at various times of the season were: mid-June, 64; mid-July, 58; early-fall (aftermath), 71 and mid-fall, 65. Molasses appeared to depress herbage digestibility. Dry matter intakes showed a seasonal trend similar to that of the herbage digestibility. The herbage intakes of unsupplemented steers weighing 570 to 780 lbs. varied from 8.7 to 15.7 lbs. of dry matter daily; whereas, the total dry matter intake of steers receiving corn or molasses as supplements was somewhat greater. The intakes of the supplemental feeds varied inversely with the dry matter intake and digestibility of the herbage.

CONTINUOUS BEHAVIOR STUDIES OF GRAZING DAIRY CATTLE. A. L. Brundage, *Alaska Agricultural Experiment Station.*

Continuous observations have been made of 8 milking dairy cattle while on pasture. They were divided into 2 equal groups. The pasture, 4 acres of smooth bromegrass (Bromus inermis), was divided into 2 equal areas. One was managed under daily rotational grazing. The other was subdivided into 4 equal paddocks and grazed under conventional rotational grazing. Continuous observations were made from the time of entry on the pasture after morning milking until removal for evening milking. Animal activity was arbitrarily divided at 5 minute intervals into one of 5 categories; grazing, standing with cud, loafing, lying with cud, or lying and loafing. Four observations have been completed at this writing. The daily rotation group was more uniform in activity and spent a higher percentage of their time grazing. After several days, however, the grazing time of the conventional rotation lot approached and even exceeded that of the others. The distribution of grazing time of the daily rotation group was fairly constant from day to day. Distribution for the conventional rotation group varied with the number of days on a specific area. The first day they were similar to the daily rotation pasture. After several days, however, they spent much less time grazing initially, even deferring grazing for several minutes, but spent more time grazing later in the day.

EXPERIENCES WITH SODIUM BISULFITE AS A PRESERVATIVE FOR GRASS SILAGE. R. L. Cowan, J. W. Bratzler and R. W. Swift, *The Pennsylvania State College.*

Experiments conducted during 1951 and 1952 have shown that anhydrous sodium bisulfite, applied in powder form to unwilted forage crops at a rate of 8 pound per ton produces silage superior in color, odor, and palatability to silages made without preservatives, or with molasses added. During storage the bisulfite-treated silage lost considerably less nutrients than did either the untreated or the molasses treated silages made from the same crops under similar conditions. Treated silages had consistently higher carotene values. Also, digestion trials with sheep showed them to be significantly higher in digestible dry matter and energy, and in TDN, probably due to decreased loss of carbohydrates by fermentation. In field trials conducted during 1952 and 1953, with 50–60 farmer cooperators throughout Pennsylvania, it was found that the powder as obtained commercially in paper bags lends itself well to farm handling and application and is inexpensive (approximately 50 cents per ton of grass treated). Many types of applicators have been tested, including gravity feed types, and mechanically driven fertilizer distributor types. Many ingenious home-made devices of both types have been used successfully, and commercial models have been placed on the market. Results observed to date, both on cooperating farms and on farms where bisulfite was used independently, indicate that all bisulfite treated silages are of excellent color and odor, being entirely free of putrefaction and butyric acid odors, and that they are highly palatable to cattle.

A STUDY OF PASTURING AND SOILING ALFALFA WITH BEEF STEERS. N. R. Ittner, G. P. Lofgreen and J. H. Meyer, *University of California.*

Interest in soiling as a method of utilizing irrigated pastures has been revived during recent years. There is, however, little experimental data in which pasturing and soiling are directly compared on the same type of forage. Since alfalfa is the crop most widely soiled in California an experiment was designed

to compare the beef produced from alfalfa when utilized by pasturing or soiling. Forty good quality Hereford steers averaging 544 pounds were divided into four lots and each lot assigned to one of the following treatments: rotation grazing, strip grazing, green soiling or wilt soiling. Each group was fed a small amount of oat hay to control bloat and scours. After 168 days on experiment there were no significant differences in the gains of the four groups, the average daily gain being 1.85 pounds. The steers on the green soiling treatment consumed an average of 60.2 pounds of alfalfa and those on the wilt soiling consumed 34.8 pounds. On the dry basis this amounted to 15.2 and 15.0 pounds respectively. After correcting for the small amount of oat hay consumed the beef produced per acre for the 168 day period was 417, 580, 704 and 568 pounds for the rotation grazing, strip grazing, green soiling and wilt soiling respectively. The beef produced from strip grazing and wilt soiling was significantly greater than that produced from rotation grazing and that produced from green soiling was highly significantly greater than that produced from rotation grazing.

DAIRY PASTURE IRRIGATION RESULTS. R. H. Lush, A. G. Van Horn, W. M. Whitaker, and B. T. Throop, *University of Tennessee and USDA.*

Three years work (1951–53) at the cooperative *Dairy Experiment Station, Lewisburg,* starting with a uniformly fertilized alfalfa-Ladino clover-orchard-grass pasture on Huntington silt loam soil has shown a very profitable response to heavy sprinkler irrigation. Two groups of Jersey cows were grazed rotationally with 8 days on each of four 1.15 acre fields from April-November 1. Cows were fed a limited amount of grain and enough hay to prevent bloat. About 1.5 inches of supplemental water was added at 10–14 day intervals or when dry. In 1951 with 24.3 inches of water in 18 applications an increase of 4838 pounds of 4 percent F.C.M. or 51 percent was obtained with a net return over feed and irrigation costs of $121.00 per acre; in 1952 with 14.8 inches of water in only 12 applications an increase of 3766 pounds of 4 percent F.C.M. or 56 percent was obtained with a net return of $110.00 per acre. Rainfall for the first two seasons averaged 20.58 inches or 7.56 inches less than normal. The first two year average was 49 percent more cow-days of grazing, 4302 pounds or 54 percent more 4-percent-fat milk with a return of $115.53 per acre above irrigation costs ($2.49 per acre-inch). More Ladino clover and less orchard-grass now remains on the irrigated sections than on non-irrigated areas, with little alfalfa except on higher non-irrigated areas. Chemical analyses of vegetation indicated little difference in crude protein, fiber and ash content for the different areas sampled either June 15 or October 15 each year.

GROWTH AND FATTENING RESPONSES IN LAMBS FED NATURAL ESTROGENIC SUBSTANCES FROM SOYBEAN OIL MEAL AND CERTAIN PASTURE AND HAY CROPS. C. D. Story, E. W. Cheng, W. H. Hale and Wise Burroughs, *Iowa State College.*

Following the detection of estrogenic substances in alfalfa and clover hays produced on the College Farm, an attempt was made to concentrate this material by alcoholic extraction of the hay and determine the influence of the extract when added to a fattening lamb ration. At about this same time genistin was isolated from soybean oil meal and shown to have estrogenic activity. Since genistin is believed to be closely related chemically to the active compound present in clover hay, it was accordingly isolated in sufficient quantity from soybean oil meal such that its influence could be tested in two lamb fattening trials. The results obtained from the alcoholic extract of clover hay produced

a slightly higher rate of gain and superior lamb carcasses as compared with a control lot of lambs receiving no extract. The first trial with genistin also resulted in a superior rate of gain and in improved lamb carcasses over the basal control lot. The second feeding trial conducted with genistin, however, failed to promote superior gains and improved lamb carcasses.

SOME CORRELATIONS BETWEEN PASTURE QUALITY AND ANIMAL PERFORMANCE IN RELATION TO SOME LIMITING FACTORS IN PASTURE EVALUATION. Marshall E. McCullough and O. E. Sell, *Georgia Experiment Station.*

Three pasture types (Pasture A, mixture of oats, ryegrass and crimson clover, B, Starr Millet and C, fescue) were studied in a two year period with producing dairy cows. A total of 26 cows were used on pasture A, 16 on B and 32 on C. For pastures A, B and C, the respective average values were (1) daily dry matter intake—35, 24 and 28 lbs. per cow, (2) dry matter digestibility—75%, 67% and 64%, (3) 14-day persistency of milk production—118%, 96% and 89%, (4) feed per lb. of milk, 1.5, 1.2 and 1.3 lbs. (maintenance included). The between-forage correlations for persistency of milk and dry matter intake was + .354, persistency of milk production and dry matter digestibility + .478. Although all correlations were highly significant, their size prevents either of the measures from being a reliable index of forage quality. When fescue data were deleted, forage dry matter intakes above 35 lb. were omitted, and data expressed in terms of Moore's formula for estimated net energy, the resulting correlations between persistency of milk production and intake of ENE was + .958. Three items apparently prevented higher correlations; (1) Fescue was incapable of maintaining milk production at any level, (2) cows on pasture A were frequently consuming more forage than their milk producing capabilities would permit them to utilize, and (3) digestible dry matter failed to show the true extent of differences in nutritive value.

POSSIBILITIES OF USING SODIUM COPPER CHLOROPHYLLINS AS AN INDICATOR IN FORAGE STUDIES. W. W. G. Smart, Jr., *North Carolina Agricultural Experiment Station and U. S. D. A.*

Preliminary investigations with rabbits to ascertain whether or not Reid's method for determining chromogen was applicable to digestion studies with switch cane leaves (Arundinaria) gave poor results. The switch cane used was relatively low in chloroplast pigments. Since the chromogen has been shown to be mainly chlorophylls and their degradation products, these were determined as copper stabilized derivatives to remove from them any other pigments occurring in the chromogen. The resulting copper stabilized chlorophylls were completely recoverable (100.27±2.60) and digestion coefficients determined were in good agreement with those determined conventionally.

LADINO CLOVER PASTURE AND GRASS-LEGUME SILAGE FOR BRED GILTS AND SOWS. S. W. Terrill, D. E. Becker, R. M. Edwards and M. C. Nesheim, *University of Illinois.*

Five lots of bred female swine were kept on one acre ladino clover pastures during the last one-half of gestation to compare the gestation performance of bred gilts under different levels of feeding and to compare the gestation performance of bred sows and bred gilts when both were given free access to minerals and ladino clover pasture but no grain or supplement. Feed per head daily in addi-

tion to pasture and minerals was as follows: Lot 1, sows, none; lot 2, gilts, none; lot 3, gilts, 2.5 lb. shelled corn; lot 4, gilts, 5 lb. shelled corn; lot 5, gilts, 4 lb. shelled corn and 1 lb. soybean oil meal. Average daily gains to farrowing time per female by lots were: (1) —0.05 (2) 0.07 (3) 0.60 (4) 1.12 (5) 1.00. Average birth weight per pig, no. of pigs farrowed per litter, no. of live pigs per sow at 1 week of age and the percentage survival of pigs to 1 week of age were by lots, respectively: (1) 2.73 lb., 10.9, 8.4, 78%; (2) 2.15 lb., 9.0, 7.3 81%; (3) 2.68 lb., 9.4, 8.6, 91%; (4) 2.69 lb., 8.7, 7.1, 82%; (5) 2.51 lb., 10.8, 9.2, 86%. In another test 3 lots of bred sows were placed on the following treatments during winter gestation on a short stand of rye pasture: Lot 1—hand-fed a well-fortified gestation ration; Lot 2—grass-legume silage (containing 20% ground corn) fed to replace as much as possible of the ration fed in Lot 1; Lot 3—self-fed a bulky ration (Lot 1 ration modified by including ground corn cobs as 25% of the ration). The gestation gains and the farrowing performance of all three groups of sows was quite satisfactory. In Lot 2, the grass-legume silage replaced 42% of the mixed ration fed in Lot 1.

Physiology Section

D. T. Mayer, *Chairman*

A YEAR'S STUDY OF THE SEMEN CHARACTERISTICS AND LIBIDO OF YOUNG BULLS SUBJECTED TO VARIOUS FREQUENCIES OF EJACULATION.

F. N. Baker, N. L. VanDemark and G. W. Salisbury, *University of Illinois.*

Nine Holstein bull calves, tested at weekly intervals, first showed sexual interest by mounting a teaser at 25–45 wks. of age and produced their first ejaculates at 36–46 wks. of age. The calves were divided at random into 3 groups of 3 bulls each from which semen samples were collected once, twice and three times per wk., collections being made over a period of one year. Volume per ejaculate, sperm concentration, total sperm per ejaculate, and total motile sperm per ejaculate generally increased in all groups during the first three quarters of the year, but did not increase in every instance in the fourth quarter. Percent motile sperm and rate of sperm motility increased through the first quarter, but did not increase through the rest of the year. The one, two and three time groups produced means of 3.12, 2.50 and 2.57 ml. semen per ejaculate with arithmetic mean concentrations of 763, 462 and 845 million sperm per ml. respectively. Although the one-time group produced the most sperm per ejaculate, both the two- and three-time groups produced more sperm per week. A reduction in libido was noted in bulls of the three-time group which was expressed by a significantly greater number of refusals to mount, and by an increase in the time taken to mount the teaser. Bulls in the one- and two-time groups and one bull in the three-time group maintained normal libido throughout the experiment.

UTILIZATION OF NITROGEN COMPOUNDS BY THE RUMEN MICROFLORA. I.

J. Belasco, *E. I. du Pont de Nemours & Co.*

The "artificial rumen" provides an *in vitro* technique for the rapid screening of nonprotein nitrogen compounds as nitrogen-feed materials for ruminants. The availability of the nitrogen of a number of such compounds to rumen bacteria was determined by employing such criteria as bacterial growth, cellulose digestion

and nitrogen utilization. The data indicate a specificity of the bacterial enzyme systems which govern the breakdown of nitrogen materials to yield ammonia, the basic unit of nitrogen, in the rumen. Thus, certain amidines, amides, inorganic and organic ammonium salts, urea derivatives and purines were found suitable as nitrogen sources for the rumen microflora.

SEMEN PRODUCTION AND FERTILITY OF MATURE DAIRY BULLS EJACULATED EITHER ONCE OR TWICE AT 8-DAY INTERVALS. R. W. Bratton, R. H. Foote and C. R. Henderson, *Cornell University.*

To date the large number of progeny from dairy sires used in artificial breeding has been the result of increased extension rates and efficiency of use of the available semen. Much less attention has been given to methods for obtaining the maximum possible number of fertile spermatozoa from sires. A twelve months study has been completed in which a group of 5 mature dairy bulls was ejaculated twice at 8-day intervals while a comparable group of 5 bulls was ejaculated once at 8-day intervals. All bulls were given a minimum of 10 minutes of sexual excitement prior to each ejaculation. During the twelve months of the experiment, the two-ejaculate bulls yielded an average of 10.3 billions of motile spermatozoa in their first ejaculates and 6.9 billions in their second ejaculates. The one-ejaculate bulls yielded an average of 10.7 billions of motile spermatozoa per ejaculate. The 60- to 90-day percent non-returns to first service cows during the first eight months of the experiment were as follows: 73.6 percent for the first ejaculates and 73.4 percent for the second ejaculates from the two ejaculate bulls and 73.3 for the one ejaculate bulls. Theses findings suggest that dairy bulls may be sexually excited and ejaculated twice at about weekly intervals with a resulting increase in spermatozoa output of at least 50 percent and without impairing their fertility.

THE RELATION OF UTERINE PHOSPHATASE CONCENTRATION TO NUMBER AND WEIGHT OF EMBRYOS IN THE RAT. Henry E. Bredeck and Dennis T. Mayer, *University of Missouri.*

This work is part of the overall investigation of the factors involved in embryonic mortality and the maintenance of viable embryos in farm animals. Since the reproductive hormones responsible for the maintenance of pregnancy are influencing uterine environment through their effect on enzyme activity, the uterine acid and alkaline phosphatase concentration and its relation to number and weight of embryos was observed. It was observed in this investigation that number of embryos and uterine weight were significantly correlated. In 57 determinations the uterine acid phosphatase was higher than the alkaline phosphatase. An increase in uterine weight was paralleled by an increase in acid phosphatase and a decrease in alkaline phosphatase. A highly significant positive correlation between the weight of uterine contents and the acid phosphatase concentration was obtained, whereas the alkaline phosphatase was negatively correlated, but the correlation was not significant. The same degree of relationship between the two types of phosphatases and number of viable embryos at the thirteenth day of gestation was observed.

SOME EFFECTS OF ESTROGEN, PROGESTERONE AND GONADOTROPHIN ON THE MATING BEHAVIOR OF EWES. Irby Bunding, M. A. Schooley, F. C. Bock and Sanford L. Steelman, *Armour and Company.*

The post parturient mating behavior of ewes as influenced by hormones and other factors was studied, using a method of indirect observation on a flock

of approximately 125 ewes. Treatments with 16 combinations of progesterone and diethyl stilbestrol were formed from 0, 0.1, 1.0 and 10 mgm. of each hormone and the interaction of these treatments with a purified pituitary gonadotrophin (FSH) was evaluated. The influence of season on the mating response, effected by the various treatments, was attained by segregating the treatments into three periods during January and March. A limited attempt was made to determine what role the sequence of hormone administration might have in modifying the mating response. By slaughtering some of the ewes, information was obtained on the conception rates effected by the treatments. Estrogen and progesterone alone stimulated breeding to about the same extent; with mixtures of these two hormones no interaction either synergistic or antagonistic could be detected. The 0.1 mgm. dose levels of estrogen and progesterone resulted in little or no response. Progesterone given simultaneously with FSH tended to suppress breeding. This was not true when estrogen was given simultaneously with FSH. The positive effects of FSH on the mating behavior was facilitated by pretreating the ewes with progesterone. A similar but somewhat lesser response was observed with estrogen pretreatments. The ewes were more responsive to hormone treatments in January than in March. Examinations of the reproductive tracts of the slaughtered ewes revealed an almost complete failure to secure conception.

ESTROGENIC ACTIVITY OF VARIOUS SYNTHETIC ISOFLAVONE DERIVATIVES AND COMPOUNDS ISOLATED FROM DIFFERENT LIVESTOCK FEEDS. E. W. Cheng, L. Yoder, C. D. Story and Wise Burroughs, *Iowa State College.*

Previous experiments have shown that extracts of clover and alfalfa hays possess estrogenic activity as detected by the mouse assay method. An estrogenic substance has also been isolated from an alcoholic extract of soybean oil meal. This substance has been identified as genistin, a glucoside of trihydroxyisoflavone. A number of related isoflavone derivatives have been synthesized chemically in this laboratory and their estrogenic activity tested. It was found that synthetic formononetin, genistein, biochanin A, and daidzein exerted considerable estrogenic activity as shown by increased mouse uterine weights when fed to immature female mice. However, it was found that these compounds on a weight basis were not as potent as stilbestrol in their estrogenic effect. Since some of these compounds are found to occur in considerable quantities in natural livestock feeds, their estrogenic activity may have a favorable influence upon the growth and fattening performance of cattle and sheep.

THE EFFECT OF A HIGH FAT RATION ON SWINE GAINS AND CARCASS QUALITY. B. N. Day, G. C. Anderson, V. K. Johnson and W. L. Lewis, *West Virginia University.*

Current interest in developing new uses for inedible fats prompted a study on the value of adding animal fats to swine rations. Control lots received a basal ration, No. 105, composed of ground yellow corn 71 percent, solvent soybean oil meal 25 percent, dehydrated alfalfa meal 2.5 percent, complex mineral mixture 1.0 percent and a vitamin supplement 0.5 percent. Experimental lots received the basal ration with the following additions: surface active agents (Armour's Ethomid C/15 alpha ethylene oxide coco amine 0.5 percent, and Arquad HT-16 a quaternary ammonium salt 0.25 percent), ration 120; prime burning lard oil 10 percent, ration 121; surface active agents as in ration 120 and 10 percent lard oil, ration 122; 0.1 percent choline chloride and 10 percent lard oil, ration 123. Duplicate lots of Duroc and Berkshire pigs were full hand-fed the above rations.

Forty-four pigs averaging 96.6 lbs. were fed to an average weight of 203.5 lbs. The average daily gain and the feed required per 100 lbs. of gain for lots on respective rations were as follows: control 105, 1.71 lbs., 361.9 lbs.; 120, 1.89 lbs., 369.8 lbs.; 121, 1.98 lbs., 311.6 lbs.; 122, 1.98 lbs., 324.7 lbs.; 123, 1.99 lbs., 333.1 lbs. Carcass grades and backfat thickness were similar for all lots. Average values of Medium Hard and Hard were obtained for carcasses produced on the fat and non-fat rations, respectively. The lard oil used had an iodine value of 69 and the average values for carcasses produced on the fat and non-fat rations were 68.1 and 62.3, respectively.

THE EFFECT OF LOW ENVIRONMENTAL TEMPERATURE ON INITIATION OF THE BREEDING SEASON AND FERTILITY IN SHEEP. R. H. Dutt, *University of Kentucky.*

Forty Hampshire-cross western ewes and six purebred Southdown rams were randomly divided into two groups of equal numbers and one group was placed in a temperature-control air-conditioned room between May 26 and October 8 to study the effect of low environmental temperature on time of onset of the breeding season and upon fertility. The air temperature was maintained within a range of 45°–48° F., and the relative humidity within a range of 70–80 percent. Natural light conditions were maintained in the temperature-control room through unshaded windows on the east and west exposures. The control group (20 ewes and 3 rams) was kept in an open pen in the barn. Both groups were fed alike. The average date of first estrus for the ewes in the temperature-control room was July 10±4.0 days and for the control ewes it was September 2±2.3 days. During July and August semen produced by the treated rams had a significantly greater percentage of motile cells and a lower percentage of abnormal cells. Ten ewes in each group were bred to treated rams and ten ewes to the control rams. Services per conception for the different groups were as follows: treated rams to treated ewes, 1.9; control rams to treated ewes, 5.3; treated rams to control ewes, 2.0; and, control rams to control ewes, 3.0. For the ewes which came into estrus and were bred early in the season, fertility of the rams kept at the low temperature was significantly higher than that of the control rams. Low environmental temperature during the summer months apparently stimulates reproductive function in ewes and is effective in improving fertility of rams.

ELECTROEJACULATION OF FARM ANIMALS. P. J. Dziuk, E. F. Graham, G. B. Marion, J. D. Donker and W. E. Petersen, *University of Minnesota.*

The purpose of this experiment was to develop a method of obtaining semen from males which are difficult to ejaculate with usual methods. A 60 cycle alternating current which could be gradually changed from 0–15 volts was used as the stimulus. This was applied by means of a rectal probe with six isolated rings. A warm saline enema was given to remove feces and to provide better electrical contact. Bulls, goats, rams and boars were ejaculated in this manner. The reasons for using this method in general practice would be either to use the semen for artificial insemination or to evaluate the semen by laboratory methods before using the male in the breeding flock. Semen obtained by this method did not differ appreciably from normal. Bulls maintained the same conception rate whether the semen was collected by an artificial vagina or by electroejaculation. Electroejaculation provides a relatively simple, quick method of obtaining semen from a large number of rams. In one instance, three men collected semen from 33 rams in 105 minutes. This semen was held for later

evaluation. Semen was also obtained very readily from male goats. Semen of sufficient volume for evaluation and quite free of accessory secretions was collected from several boars. Electroejaculation can be used as an aid in obtaining viable spermatozoa from several domestic species.

THE MAMMARY GLAND SPREADING FACTOR. J. R. Elliott and C. W. Turner, *University of Missouri.*

Investigation has revealed that a mammary gland spreading factor present in the albino rat, albino mouse, guinea pig and rabbit during pregnancy increased in amounts during early gestation until a peak was reached in from half to two-thirds of pregnancy after which it declined until none was present at parturition. Injection of a number of hormones, which induce duct and lobule-alveolar growth of the mammary glands, has shown them to be effective in causing elaboration or activation of the mammary gland spreading factor. Estrogen and progesterone separately or together, pituitary extracts, testosterone, desoxycorticosterone, cortisone and relaxin were all shown to be effective to a greater or lesser degree in causing production of the active spreading factor.

SOME EFFECTS OF SOURCE OF PROTEIN AND AN ANTIBIOTIC ON REPRODUCTIVE PERFORMANCE IN GILTS. S. H. Fowler and G. L. Robertson, *Agricultural and Mechanical College of Texas.*

Four lots of 5 gilts each were used to test the effects of the various combinations of animal and vegetable protein and presence or absence of chloromycetin on reproductive performance in gilts. All lots received a vitamin B_{12} supplement and were self-fed by treatment groups. Animal protein (AP) lots attained puberty at an average age of 213 days as compared with 229.9 days for vegetable protein (VP) lots ($P<.05$). Gilts receiving chloromycetin averaged 1.6 days older at puberty in AP lots and 9.3 days younger in VP lots ($P>.05$). All gilts were bred at second estrus and slaughtered 25 days thereafter to secure ovulation and embryo survival data. Ovulation rate for AP gilts at second estrus was 11.7 ova as compared with 10.8 for VP gilts ($P>.05$), and there was an overall advantage of .7 ova per gilt in favor of gilts not receiving chloromycetin ($P>.05$). AP gilts averaged 8.5 normal embryos as compared with 8.0 for VP gilts ($P>.05$), and gilts receiving chloromycetin averaged 8.6 as compared with 8.0 for gilts not receiving the antibiotic ($P>.05$). VP gilts had 74.06 percent of ova shed represented by normal embryos and AP gilts 75.38 percent; gilts receiving chloromycetin averaged 81.48 percent as compared with 68.46 percent for gilts not receiving the antibiotic ($P>.05$). Hemoglobin levels averaged 11.20 and 11.64 gm. per 100 cc. of blood for VP and AP gilts receiving chloromycetin as compared with 10.86 and 10.88 for VP and AP gilts not receiving chloromycetin ($P>.05$).

AN INVESTIGATION OF THE PROTEIN-BOUND IODINE WITH ITS CORRELATION TO AVERAGE DAILY GAIN AND MORPHOLOGICAL VARIATIONS. A. Gawienowski, D. T. Mayer and J. F. Lasley, *University of Missouri.*

A preliminary study was made of the protein-bound iodine (PBI) of twenty young purebred Hampshire gilts and barrows, slaughtered at an average weight of 215 pounds. The average daily gain, back fat thickness, left hind leg growth and body length growth were recorded and their relation with the PBI determined. The correlation between the PBI and the average daily gain was negative and proved to be highly significant ($P\leq 0.01$). There was a trend for the body lengths to decrease as the PBI values increased; also for the length of the hind

leg and the average back fat thickness to decrease as the PBI increased, but the correlations were not significant. The PBI method used was an alkaline ash procedure modified in this laboratory to facilitate its use in studies of this nature.

FACTORS AFFECTING REFLEX CLOSURE OF THE ESOPHAGEAL GROOVE IN THE CALF. R. B. Hegland, N. L. Jacobson and L. C. Payne, *Iowa State College.*

Rumen fistulas were prepared in four calves at ages ranging from 9 to 18 days. Each fistula was fitted with a flexible rubber "sleeve" which minimized irritation, facilitated prompt initiation of frequent intraruminal (and intrareticular) examinations and permitted closure of the fistular opening by use of a plastic cover on the exterior end of the sleeve. The effects of various liquids (whole milk, reconstituted skimmilk, reconstituted whey product and water), method of feeding (nipple pail vs. open bucket), and administration of gelatin capsules on the reflex closure of the esophageal groove were determined. All of the liquids studied effected complete closure of the esophageal groove in all calves to 8 weeks of age, and during this period the two methods of feeding were equally efficient. Nipple pail feeding continued to stimulate closure of the groove in all calves up to 100 days of age, whereas open bucket feeding was less effective subsequent to 8 weeks. As age advanced, water was the first of the liquids to lose effectiveness in stimulating closure of the esophageal groove. When capsules, ranging in size up to 5/8 inches in diameter and 1 5/8 inches in length, were administered concomitantly with the various liquids, all capsules passed readily through the groove to the omasum. Essentially all capsules, regardless of size, were deposited in the reticulum when no liquid was consumed concurrently by the calf. The degree of closure of the esophageal groove was not influenced by the feeding of hay, grain and water *ad libitum.*

STIMULATION OF GROWTH AND FATTENING IN LAMBS WITH PROGESTERONE-ESTROGEN COMBINATIONS. H. A. Henneman, R. Rust and J. Meites, *Michigan State College.*

Two experiments were conducted with 90 and 33 Texas lambs averaging 80 pounds and 74 pounds respectively. Both experiments included controls and a treatment of 250 mg. progesterone and 10 mg. estradiol. Hormone pellets were implanted subcutaneously. Other treatments in Experiment I were progesterone, estradiol, testosterone and synthetic androgen. In the first experiment the lambs were all slaughtered when one of the lots averaged 100 pounds and, therefore, the feeding period following implantation was 28 days. Only the lambs receiving the combination of progesterone and estradiol compared favorably to the controls having a 27 percent higher rate of gain on 15 percent less feed per pound of gain; and they were not significantly different from the controls in carcass grade, dressing percent, percentage of moisture, or in other factors which were studied. There was no interraction between sex and treatment. In the second experiment a third lot received 100 mg. of progesterone and 10 mg. of estradiol. These lambs were fed 42 days after implantation. Lambs implanted with the 10:1 ratio gained 42.5 percent faster on 24.6 percent less feed per pound of gain but dressed 1.6 percent lower than the controls. In all other factors studied they were equal to the controls. Lambs implanted with a 25:1 ratio gained 35.5 percent faster on 22.8 percent less feed per pound of gain but dressed 1.5 percent lower and the fat contained 2.2 percent more moisture than the controls. The accessory sex glands of the lambs receiving the combination treatments showed, hyperplasia, cystic dilatation, and keratinization of the epithelial structures.

SIMULTANEOUS DETERMINATION OF EXTRACELLULAR AND TOTAL BODY WATER IN RUMINANTS USING SODIUM THIOCYANATE AND ANTIPYRINE AND ITS VALUE IN NUTRITION STUDIES. Elliott Lee Hix, *Kansas State College.*

Normal extracellular water (ECW) volume ($^{-}$SCN space) in sheep and goats is extremely consistent at 30 percent of body weight. Cattle 6–8 months of age show a range of 27.6–29.7 with a mean value of 28.2 percent. This range of values may be due in part to the inability to weigh an animal of this size accurately. In cattle the ECW appears to vary directly with total body water (TBW) and inversely with body fat. Thiocyanate ($^{-}$SCN) is slowly metabolized by the Ovine at 4–5 percent of the injected dose per hour, while the Bovine shows a consistent serum concentration of $^{-}$SCN for 6 hours post-injection. Renal tubular absorption of $^{-}$SCN is apparently complete in the Bovine. TBW in all species varied between 53 and 66 percent of body weight and varied inversely with body fat. Antipyrine is metabolized by the Ovine at the rate of 31 percent per hour of the injected dose, while in the Bovine its metabolism is slower by approximately 5 percent. Thiocyanate and antipyrine are determined spectrophotometrically after phasic separation from a 2 ml. serum sample. A simultaneous determination of ECW and TBW has the advantage of (1) indicating body fluid shifts, (2) in relating ECW values between species to the fat-free body mass, and (3) body composition after physiological maturity. Much physiologic data can be obtained by this means from nutrition experiments thus broadening the interpretation considerably.

EFFECT OF STILBESTROL, STILBESTROL-PROGESTERONE IMPLANTS ON FATTENING LAMBS. R. M. Jordan, *South Dakota State College.*

Four lots of 25 lambs each were full-fed four different fattening rations; Lot 1 corn, alfalfa hay and soybean meal; Lot II hulless oats, alfalfa hay and soybean meal; Lot III corn, 2½ pounds alfalfa silage, ½ pound alfalfa hay and soybean meal; Lot IV, same as Lot III except 2½ pounds corn silage substituted for the alfalfa silage. Five lambs from each lot were selected at random and received a 6 mg. pellet of stilbestrol subcutaneously and 5 lambs from each lot were selected at random and received a 6 mg. pellet of stilbestrol and a 50 mg. pellet of progesterone. Average daily gain per lamb in the four lots for the untreated, stilbestrol and stilbestrol-progesterone treated lambs respectively was as follows: Lot I .36, .50 and .49 pound; Lot II .43, .58 and .52 pound; Lot III .41, .63 and .51 pound; Lot IV .41, .52 and .47 pound. Carcass data were gathered on the untreated, stilbestrol, and stilbestrol-progesterone lambs as 3 groups rather than by the lot in which they were fed. Carcass yield was 50.1, 49.1 and 49.2 percent for the untreated, stilbestrol and stilbestrol-progesterone lambs respectively. Of the control lot 30 percent graded prime and 70 percent choice. None of the stilbestrol treated lambs graded prime, 81 percent choice, 12.5 percent good and 6 percent utility. Six percent of the stilbestrol-progesterone treated lambs graded prime, 75 percent choice and 12½ percent good. One ewe lamb treated with 6 mg. stilbestrol died from a prolapsed uterus.

THE INFLUENCE OF SEX HORMONES UPON RATE AND EFFICIENCY OF GAIN OF FATTENING CALVES. Earle W. Klosterman, L. E. Kunkle and A. L. Moxon, *Ohio Agricultural Experiment Station.*

Two experiments have been conducted to determine the influence of age of castration upon the feed lot performance of fattening Hereford calves.

In both experiments one group of calves was castrated shortlty after birth, one group was castrated at weaning age, and a third group was fed as bulls. The feed lot performance of steers castrated either at birth or at weaning was practically identical. In one experiment when the bulls and steers were fed for the same length of time the bulls gained 0.23 pound per head daily faster than the steers. When fed to a similar weight in the second experiment the difference in average daily gain was 0.48 pound. These differences proved to be statistically highly significant. In a third experiment, one lot of calves was castrated at weaning and one after being fed for 100 days. Bulls and bulls implanted subcutaneously with diethylstilbestrol (25 mg./cwt.) were also fed. In this experiment bulls gained approximately one-third pound per head daily faster than steers and bulls implanted with diethylstilbestrol one-third pound faster than untreated bulls. The results of this one experiment indicate that the effects of the male sex hormones as produced by normal bulls and of diethylstilbestrol, at the level used, were additive rather than antagonistic.

THE MEANING OF HEAT TOLERANCE AS APPLIED TO DOMESTIC ANIMALS. Douglas H. K. Lee and R. E. McDowell, *Johns Hopkins University and U.S.D.A.*

Heat tolerance is the name given to the animal's ability to escape adverse consequences of the direct operation of hot conditions. There are different ideas, however, as to what change in animal function should be used as a measure of heat tolerance. Some physiologists think of changes in body temperature as *the* criterion of heat tolerance, making the assumption that disturbances in other functions will run parallel. Most animal producers think rather in terms of productivity, taking changes in output as indices of heat tolerance. Many other functions have been used as indices, but are all open to objection. The term "heat tolerance" really applies to the way in which the animal as a whole reacts, while what is measured is but an aspect of the whole. The advantages and disadvantages of each index must be recognized, and an attempt made to effect a mental synthesis of the various aspects.

MEASUREMENT OF WATER EVAPORATION FROM SELECTED AREAS OF HIDE IN DOMESTIC ANIMALS. R. E. McDowell, D. H. K. Lee and M. H. Fohrman, *U.S.D.A. and Johns Hopkins University.*

A method of measuring water evaporation from small areas of skin is described which avoids the disturbances likely to be introduced by the usual methods using dry air. Air is recirculated by a pump alternately through a capsule applied to the skin and an absorber containing a saturated solution of a suitable salt. The air leaves the absorber with a vapor pressure determined by the salt solution, picks up water vapor while passing over the skin under the capsule, and deposits this excess water vapor in its next passage through the absorber. The rate of evaporation is determined by serial weighing of the absorber to 0.1 mg. Two circuits are employed: (i) a measuring circuit, in which the capsule over the area being studied at the moment is included; and (ii) a maintenance circuit, in which all capsules are included during such times as evaporation is not actually being measured in them. In this way accumulation of moisture in the capsules between measurements is prevented.

ASCORBIC ACID CONTENT OF THE CORPORA LUTEA, FOLLICLES, AND OVARIES OF SWINE DURING THE ESTROUS CYCLE. W. W. Moore and A. V. Nalbandov, *University of Illinois.*

The ascorbic acid content of the corpora lutea, follicles and the ovaries of 23 swine was determined at various intervals throughout the estrous cycle. Fifteen days out of the 21 day reproductive cycle were investigated. The method used for the determination of ascorbic acid was that of Roe and Kuether and the amount of ascorbic acid in each part was expressed in terms of gamma per gram of dried tissue. The results were correlated with the total gonadotrophic, thyrotrophic and adrenocorticotrophic hormone contents of the anterior pituitary gland and the ovarian and uterine morphology. The results indicate that the ascorbic acid content of the corpora lutea is not detectable on day 1 of the cycle. After ovulation the content rises sharply until day 4 to 1800 gamma/gram of dry tissue and remains constant until day 10 after which it decreases linearly until the next ovulation. The ascorbic acid content of the corpora lutea is directly related to the size of the corpora lutea, the secretory endometrium, and inversely related to the total AP gonadotrophin content and the follicle index. The ascorbic acid content of the follicles shows no trend (ave., 980 gamma/gram of dry tissue), but is quite variable throughout the estrous cycle and reaches a peak just prior to ovulation. There was no significant trend in the ascorbic acid content of the ovaries during the estrous cycle.

EFFECT OF PROLACTIN ON CORPUS LUTEUM FUNCTION IN THE EWE. W. W. Moore and A. V. Nalbandov, *University of Illinois.*

The effects of prolactin on the function and morphology of the corpus luteum were studied on ewes during the breeding season and following gonadotrophic hormone-induced ovulations during the non-breeding season. Each of ten ewes was given one intramuscular injectiton of 200 I.U. of prolactin daily, starting on day 2 of the estrous cycle until the occurrence of the next heat. Prolactin-treated ewes had estrous cycles with a mean length of 20.9 ± 2.02 days, as compared to the normal cycle length of 16.1 ± 0.15 days. These differ significantly at the 5 percent level. Each of 30 anestrous ewes was ovulated with one intravenous injection of 100 C.N.U. of PMS; of these 11 received no further treatment, and 19 received daily intramuscular injections of 200 I.U. of prolactin until the time of autopsy, either 15, 20 or 30 days after ovulation. The criteria used to judge corpus luteum function were the histological appearance of normal luteal tissue and a secretory endometrium. Fifteen days after ovulation both groups had functional luteal tissue. At 20 days luteal tissue was still functional following prolactin treatment, marked luteal degeneration occurred in the untreated animals and their endometria were atrophic. At 30 days the control animals had no functional luteal cells and their endometria had the appearance of that of anestrous ewes. The prolactin treated ewes had many functional luteal cells and typical secretory endometria. These studies indicate that prolactin has a luteotrophic action in the ewe.

EFFECT OF STILBESTROL AND THIOURACIL ON THE UTILISATION OF NUTRIENTS IN SHEEP. D. N. Mullick, V. N. Murty and N. D. Kehar, *Indian Veterinary Research Institute.*

An investigation was made on twelve healthy adult male sheep, divided into three identical groups of four each, to study the influence of the subcutaneous implantation of 20 mgm. of stilbestrol and of feeding 1 gm. of thiouracil daily

with the concentrate, on the metabolic turnover of the proximate principles and minerals. The animals were given a ration consisting of 4 oz. ground nut cake, 12 oz. barley and oat hay *ad lib.* No significant differences were recorded either in the intake or the coefficient of digestion of the proximate principles. The average consumption of dry matter and the total digestible nutrients showed no significant differences between the control and experimental groups, though the animals in the thiouracil group showed lower ingestion of dry matter and T.D.N. The intake and retention of nitrogen, calcium and phosphorus, and the metabolism of water were not affected significantly by the treatments. Records of the electrocardiogram in experimental animals showed slower rate of heart beat and potentials in QRS and T waves were greater as compared to the control group.

SEASONAL VARIATIONS IN THE NITROGEN, CALCIUM AND PHOSPHORUS METABOLISM IN CATTLE. D. N. Mullick, V. N. Murty and N. D. Kehar, *Indian Veterinary Research Institute.*

The data were collected from the metabolism trials conducted on six adult Kumaoni hill steers of 300–400 lbs. body weight, during the four seasons when the average temperature in ° F. and percentage relative humidity were 86 and 42, 98 and 33, 88 and 81 and 64 and 50 respectively. The mean daily intake and retention for the spring, summer, autumn and winter were 35.42 and 1.09, 29.26 and —3.11, 29.28 and 1.09, 36.03 and 1.20 gms. of nitrogen, 8.99 and —0.01, 7.28 and —5.00, 9.59 and —1.46, and 9.89 and 0.27 gms. of calcium; 7.29 and 0.71, 6.06 and 0.20, 7.27 and 0.33, 8.22 and 1.11 gm. of phosphorus respectively. It may be concluded that the requirement of calcium is higher in summer, and that of nitrogen and phosphorus slightly higher in winter. It was noted that the animals preferred the roughage in summer months. The dietary wisdom of the animals to climatic stress, coupled with the negative balances for nitrogen and calcium, in summer, would necessarily warrant the need for providing roughage of better nutritional value, like hay or silage, instead of the cereal straws.

A STUDY OF THE EFFECTS OF TESTOSTERONE CYCLOPENTYLPROPIONATE ON THE SEMEN CHARACTERISTICS AND SEXUAL BEHAVIOR OF BEEF BULLS. R. L. Murphree, E. V. Long and C. S. Hobbs, *University of Tennessee.*

The objectives of this study were to obtain information regarding the effects of prolonged treatment with testosterone on the semen characteristics and sexual behavior of beef bulls. A preliminary trial with one bull, which was producing high quality semen but was lacking in sexual desire, suggested that such treatment might be beneficial in the treatment of some slow-breeding bulls. However, there is the possibility that extended treatment might depress semen quality. Six young Hereford bulls were used in a preliminary study of the effects of weekly injections of testosterone cyclopentylpropionate. Two bulls received no treatment and provided the control data. Two of the treated bulls provided data on semen characteristics and sexual behavior. The data obtained in this study fail to show that weekly injections of 100 or 200 mg. of testosterone cyclopentylpropionate for eight to fifteen weeks produced any measurable changes in the semen characteristics which could be attributed to the treatment. Likewise, no marked changes in sexual behavior were noted in these bulls. Two other treated bulls, from which no semen was collected, provided data only on sexual behavior. No

beneficial response was observed during or following treatment in one bull showing anaphrodisia or in another bull which was unable to get a complete erection of the penis.

A NOTE ON THE EFFECTIVE BUOYANCY OF RUMEN JUICE OF CATTLE FED HAY, GRASS AND LEGUMES. R. E. Nichols, W. E. C. Moore and R. D. Dillon, *University of Wisconsin.*

The effective buoyancy of a complex substance like rumen juice is determined by the quantity and specific gravity of all its components—liquid, solid and gaseous. Samples of strained and of centrifuged rumen juice collected from the ventral sac of the rumen were weighed at rumen temperature in specific gravity bottles and results averaged for 3 fistulated cows before, shortly after and at a later time after intake of water, hay, young green grass, prebloom alfalfa and mixed clover. Drinking water apparently lowers the specific gravity of the fluid portion of rumen juice. Eating green feed apparently lowers the specific gravity and consequently the effective buoyancy of strained rumen juice even when the liquid portion of the juice is not diluted by water intake. The decrease in buoyancy and the rate of bubble formation of strained juice was greatest with legumes.

EFFECT OF FEEDING THYROPROTEIN ON MILK PRODUCTION, BUTTERFAT PERCENTAGE AND BODY WEIGHT OF EGYPTIAN BUFFALOES. Mohammed M. Oloufa, *Fouad University.*

Eight mature female buffaloes were divided at random into two groups of equal numbers. One group served as control, while the other received Protamone (supplied by Cerophyl Laboratories, Inc., Kansas City, Mo.) at the rate of 15 gm. per animal per day after six weeks of parturition for 18 weeks. In addition to their calculated ration, thyroprotein-fed animals only were given 3 lbs. of extra feed daily. All animals were milked twice daily and the butterfat percentages were determined once every week. The buffaloes were also weighed at weekly intervals. The animals varied in their response to thyroprotein feeding. On the average, feeding thyroprotein caused an increase of 4.18 percent in milk production and 4.95 percent in butterfat percentage over the control. The animals were heavier at the end of the experiment than their initial weights, and thyroprotein was almost without effect on body weight when compared with the control. Conceptiton rate was higher in the control than in the thyroprotein-fed group. All the above differences between the two groups lacked statistical significance. It could be concluded that feeding thyroprotein to Egyptian buffaloes might be beneficial to milk production and butterfat percentage. A higher dosage of thyroprotein should be tried on a larger number of animals for a longer period of time than the case in the present investigation.

THE EFFECTS OF STILBESTROL ON THE PERFORMANCE OF FATTENING STEERS FED BLACKSTRAP MOLASSES. C. C. O'Mary, E. P. Warren, T. J. Davis and H. H. Pierce, *University of Georgia.*

Fifty grade Angus and grade Hereford steers were divided into five lots of 10 steers each. The steers were fed a basic supplement plus varying proportions of blackstrap molasses to cottonseed hulls. Five steers in each lot were implanted in the ear with 36 mg. of stilbestrol pellets and after 42 days two of the initially treated steers were reimplanted with an additional 36 mg. of stilbestrol. During the first 42 days the 25 treated steers gained highly significantly

faster with 2.26 pounds per steer per day compared to 1.88 for the controls. During the last 63 days the control steers gained an average of 0.97 pound per day. The initially treated steers gained 1.38 pounds while the reimplanted steers gained 1.41 pounds per day. Both treated groups gained highly significantly faster than the control steers but there was no difference between the two treated groups. There were no ration treatment interactions in either the first or second period. There was a visibly detectible "depression of the loin" of the treated steers as confirmed by scores of five judges working independently. The average weights of the seminal vesicles (one from each steer) were 5.84, 12.63 and 13.37 gms. for the control, initially treated and reimplanted groups, respectively with both treated groups being increased highly significantly over the controls. There were no significant differences between the controls and either of the treated groups in shrinkage from feedlot to market, dressing percentage or carcass grade.

BLOOD UREA AND AMMONIA LEVELS IN LAMBS FOLLOWING ORAL ADMINISTRATION OF GRADED AMOUNTS OF FIVE EXPERIMENTAL NON-PROTEIN NITROGEN FEEDING COMPOUNDS. W. W. Repp, W. H. Hale and E. W. Cheng, *Iowa State College.*

Five experimental non-protein nitrogen feeding compounds (urea, ammonium propionate, propionamide, ammonium formate and ammonium acetate) were administered orally to lambs for purposes of determining their relative toxicity and usefulness as livestock feeds. The materials were given as drenches at various dose levels. The initial dose level was 10 gm. of urea (or its nitrogen equivalent in the case of the other compounds) per 100 pounds body weight. Dose levels were progressively increased at a rate of 5 gm. of urea equivalent until at least half of the lambs succumbed. Blood samples were taken before and at varying lengths of time after administration of the respective compounds. The blood ammonia values obtained reached a maximum at approximately 30 minutes after drenching. The blood urea values rose slowly and were still increasing three hours after drenching. Toxicity was encountered at the 25 and 30 gm. urea equivalent levels with the lambs receiving ammonium propionate and at the 40 gm. urea equivalent level with the lambs receiving urea, ammonium formate and ammonium acetate. The treated lambs were able to tolerate blood ammonia levels as high as 1.0 mg. per 100 ml. No toxicity was encountered among the lambs drenched with propionamide even when administered at very high levels (80 gm. urea equivalent). This compound also behaved different from any of the other compounds tested in that blood urea and blood ammonia were not elevated following drenching.

A CYTOLOGICAL STUDY OF THE MATURATION PROCESS OF NORMAL AND ARTIFICALLY OVULATED OVA IN THE EWE. H. P. Savery and R. O. Berry, *Texas A. & M. College.*

Normally the nucleus of the ovum undergoes a series of changes prior to ovulation in preparation for fertilization. Cytological observations of the nucleus of the ovum from the ewe reveals that by mid-estrum the chromosomes have undergone a change from that of the meiotic prophase to that of the metaphase stage of the first maturation division. Just prior to ovulation the nucleus quickly completes the first maturation division resulting in formation of the first polar body and subsequently an egg nucleus in the second metaphase stage. It is in this stage the matured ovum is ovulated and awaits fertilization. At the time of ovulation, the ovum is embedded within an ovulation plug which is later

dispersed in the oviduct. If the ovum fails to become fertilized, the nucleus breaks down and finally becomes pycnotic and the ovum undergoes fragmentation or other means of degeneration. Ovulation was induced in 78 luteal phase and 24 anestrous ewes by injections of 20–35 Armour units of gonadotropin. Estrus was not observed in any ewe as a result of injections of gonadotropin alone, however, estrus and ovulation was obtained when the gonadotropin was supplemented with 10–15 mg. of stilbestrol. Follicular growth and maturation of the nucleus was stimulated in all animals injected with the gonadotropin alone or in combination with stilbestrol. Some follicles as small as 4 mm. in diameter contained an ovum with a nucleus which had completed the first maturation division. All ova examined from the oviducts exhibited a nucleus in the metaphase stage of the second division which is the condition of normally ovulated ova. Fertilization was attempted in 68 ewes without success. The eggs did not undergo cleavage and no sperm were observed in the zona pellucida.

THE EFFECTS OF VARIOUS SEQUENCES OF FULL AND LIMITED FEEDING ON THE REPRODUCTIVE PHENOMENA IN CHESTER WHITE AND POLAND CHINA GILTS. H. L. Self, R. H. Grummer and L. E. Casida, *University of Wisconsin.*

Thirty-two Chester White (CW) and 32 Poland China (PC) gilts were divided into 4 groups; each group was fed a different sequence of feed levels and the effects determined on certain reproductive phenomena. All gilts were bred at second heat—one-half of each group was slaughtered 24–48 hours after heat; the other half was slaughtered 25 days after breeding. The four sequences of feeding levels were: (1) FF—full-fed from 72 days to slaughter; (2) FL—full-fed from 72 days to puberty then changed to limited feed (approximately two-thirds the level of full-fed gilts); (3) LF—limited-fed from 72 days to puberty then changed to full feed; (4) LL—limited-fed from 72 days to slaughter. Average puberal age for all animals was 215.7 days (SD—29.2). The CW averaged 224.9 days and the PC 206.5 days ($P<.01$). Full-fed gilts were older at puberty than limited-fed gilts (223.3 vs. 208.2; $P<.01$). The average first heat ovulation rate of all animals was 11.06 (SD—2.27). The breed means were significantly different (CW—11.94 and PC—10.19; $P<.05$). Full-fed and limited fed groups averaged 11.88 and 10.25 ova respectively ($P<.05$). Second heat ovulations averaged 1.35 ova more than the first heat and the breed difference was still evident (CW—13.89 and PC—11.70; $P<.01$). Second heat breed-treatment group ovulation rates were: PC-FF—12.0; PC-FL—10.75; PC-LF—11.75; PC-LL—9.50; CW-FF—15.5; CW-FL—11.5; CW-LF—15.25; CW-LL—13.0. The over-all fertilization rate was 96 percent. A slightly higher percent of embryo survival enabled the PC to have approximately the same number of embryos (5.33) as the CW (5.07). Regardless of prepuberal feed level, gilts full-fed from puberty to slaughter tended to have approximately 25 percent fewer embryos than corresponding limited-fed gilts. Embryo survival for the four groups were FF—32 percent; FL—49 percent; LF—39 percent; and LL—57 percent.

SERUM VALUES IN "WHEAT PASTURE POISONING" CASES. Frank H. Sims and H. R. Crookshank, *Texas Agriculture Experiment Station and U.S.D.A.*

The comparison of various serum components from 17 cases of "wheat pasture poisoning" in cows and from 185 "normal" cows grazing wheat pasture revealed some differences in serum composition. There appears to be a decrease in total and ionic or diffusible calcium, magnesium and the albumin-globulin ratio in "wheat pasture poisoning" cases. The affected animals showed an increase in

serum potassium and total protein while the serum albumin remained about constant. Because of extreme variation, no comparison was made of the alkaline phosphatase activity and of the inorganic phosphate. No data were available on "wheat pasture poisoning" in sheep for comparison with the data from 149 "normal" ewes.

THE EFFECT OF VARYING DILUTER CONSTITUENTS UPON OSMOTIC BEHAVIOR OF EXTENDED BULL SEMEN DURING STORAGE. J. T. Smith and D. T. Mayer, *University of Missouri.*

Semen from healthy dairy bulls was extended with diluents designed especially to alter one or more of the physical or chemical properties of the diluent. These extended semen samples were stored at 4 to 7° C. and evaluated daily for both motility and freezing point depression. Motility was rated according to standard methods, while freezing point depression was determined using a modification of the Hill-Baldes thermoelectric osmometer. Results of the investigation have shown that added glucose was a necessary constituent of a diluting fluid if the diluent was to maintain the osmotic pressure of the extended semen within narrow limits throughout the storage period. The osmotic behavior of extended semen was indicated to be independent of the buffer salt used in the diluent. However, addition of antibiotics to the diluent resulted in the maintenance of a lowered osmotic pressure by the extended semen throughout the storage period.

THE EFFECT OF MODERATE STATES OF VITAMIN A DEFICIENCY ON REPRODUCTIVE PERFORMANCE IN GILTS. H. S. Teague, L. E. Carpenter and L. M. Winters, *University of Minnesota.*

In two studies lowered plasma vitamin A levels were established and maintained in gilts previous to and during gestation to observe the influence of a partial deficiency of this vitamin on reproductive performance. White corn was used in formulating the low-carotene diets. In the first study all bred females were sacrificed after an average of 31 days of gestation. Early prenatal survival of litters was not decreased in the gilts maintained with an average plasma A level 73 percent of that of control gilts which received an 18.5 percent alfalfa ration. Retinal folding was seen in histological sections of the eye region of embryos from two A depleted gilts. Early reproductive performance of a third group was not improved by the addition of supplemental vitamin A to the alfalfa containing ration. In the second study lower plasma A levels were maintained—one group near 40 and another near 50 percent below their average pre-experimental levels. Some females were sacrificed after approximately 30, and others 70 days of gestation. Individual cases of high prenatal mortality were observed in litters from deficient dams. Eye anomalies were more frequent in embryos from A deficient gilts but no case of retinal folding was encountered. The performance of the partially depleted gilts allowed to farrow ranged from good to poor. No grossly abnormal pigs were observed at birth.

THE EFFECT OF AUREOMYCIN UPON GROWTH, DIGESTION OF RATION CONSTITUENTS, RECTAL TEMPERATURES AND URINE VOLUME OF SHEEP. Allen D. Tillman and Robert W. MacVicar, *Oklahoma Agricultural Experiment Station.*

One group of eight sheep was group-fed a basal ration composed of 66 2/3 percent concentrates and 33 1/3 percent coarsely ground prairie hay for 84 days while a second group of eight received the same ration plus aurofac 2A. (Gen-

erously supplied by Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York.) To supply 5 mg. of aureomycin/pound of ration. The results are based upon eight sheep finishing the test on the basal diet and seven in case of the group receiving aureomycin; one animal became sick and was removed. The animals receiving the basal diet had an average daily gain of 0.26 pounds and required 9.9 pounds of feed/pound of gain while those receiving aurotac gained 0.31 pounds per day and required 8.7 pounds of feed/pound gain. For the digestion trials, ten sheep were divided into two equal groups; one group receiving the basal ration and the other aureomycin-HCl to supply 10 mg. aureomycin-HCl per sheep/day. The daily ration consisted of 454 grams of concentrates and 454 grams of prairie hay. The animals were kept in the metabolism stalls for 20 days; a 10-day preliminary period followed immediately by a 10-day collection period. At the end of the first collection period, the ten animals were placed in one holding pen and fed a standard ration for 10 days. The lambs were then switched and returned to the metabolism stalls. Aureomycin had no effect upon the digestibility of ration constituents in either of the two trials. After the second digestion trial was completed, the animals were continued on feed for 6 more days during which time rectal temperature of each sheep was taken at the same time each day and the volume of urine excreted during the past 24 hours weighed. The average rectal temperatures were 39.93° C. and 39.77° C. for the basal and aureomycin groups, respectively. The average daily excretion of urine was 898 and 1136 grams per sheep/day for the basal and aureomycin groups, respectively.

THE EFFECT OF DAILY INJECTIONS OF EPINEPHRINE ON SEMEN PRODUCTION OF BULLS. N. L. VanDemark and F. N. Baker, *University of Illinois.*

The effect of daily injections of epinephrine on semen production was studied with a group of nine two-year-old bulls. Epinephrine was administered to simulate mishandling. Semen characteristics including volume, sperm concentration, initial sperm motility, pH, and the percentage of morphologically abnormal sperm, were determined on ejaculates from five treated and four control bulls during four consecutive ten-week periods. Observations were made during a pretreatment period, a period in which the treated bulls received intravenously 2 ml. (1 to 1000 solution) of epinephrine daily, a period in which 5 ml. epinephrine (2 ml. intravenously and 3 ml. subcutaneously) were given daily, and a final post treatment period. Epinephrine treatment caused a reduction in semen volume and sperm concentration. This effect was more pronounced when the dosage was increased. The bulls in the treated group produced 94 percent of the total number of sperm per ejaculate produced by the control group during the pretreatment period, 86 percent when they were receiving 2 ml. epinephrine daily, 67 percent when 5 ml. epinephrine was administered daily and returned to 85 percent during the ten-week post-treatment period.

THE INTRACELLULAR LOCALIZATION OF I^{131}-TAGGED LACTOGENIC HORMONE IN THE MAMMARY GLAND OF THE RABBIT. Walter F. Williams and C. W. Turner, *University of Missouri.*

Lactogenic hormone (Squibb #71713) was tagged with I^{131} by the method of Stadie *et al.* (Jour. Biol. Chem. 199:729, 1952). Lactogenic-I^{131} hormone was injected intraductally into the mammary glands of 15-day pseudopregnant rabbits according to the assay procedure of Lyons (Proc. Soc. Exp. Biol. Med. 51:308, 1942). Thirty minutes after the final injection the animals were killed, the

mammary glands dissected free, ground, and washed to remove free lactogenic-I^{131} hormone. The washed tissue was then homogenized and the homogenate fractionated by the procedure of Schneider (Jour. Biol. Chem. 183:123, 1950) and Wilbur and Anderson (Exp. Cell. Res. 2:47, 1951). The various cytological fractions thus obtained were wet ashed with KOH, dried in cups, counted, and corrected for self-absorption. It has been found consistently that 85–90 percent of the lactogenic-I^{131} hormone is associated with the particulate fractions of the cell, the mitochondria and microsomes. Three to six percent of the activity is associated with the nuclei, and five to ten percent with the supernatant fraction. The activity of the particulate fraction is about equally divided between the mitochondria and the microsomes. The distribution of physiologically inert proteins e.g. casein and rabbit blood serum proteins is being studied, as is the mode of binding of the lactogenic hormone.

SOME EFFECTS OF SEXUAL AGE ON REPRODUCTIVE PERFORMANCE IN GILTS. F. S. Wise and G. L. Robertson, *Agricultural and Mechanical College of Texas.*

Twenty-four fall-farrowed Duroc gilts were allotted to three groups of eight gilts each and bred at first, third, or fifth heat periods. All gilts were self-fed in one lot until they averaged about 175 pounds in weight when the feed was somewhat limited to prevent overfatness. Overall age and weight at puberty was 212.5 days and 190.6 pounds. Date of birth in the farrowing season apparently was not associated with age at puberty ($r = -.06$). Four gilts in each group provided information on ovulation and fertilization rates while the remaining gilts provided an estimate of ovulation rate and embryonic mortality. Ovulation rate for first, third, and fifth heat periods averaged 14.0, 12.2, and 12.5, respectively. Apparently the reduction in daily feed allowance was responsible for the reduction in ovulation rate in those gilts which were limited-fed over the longest period prior to slaughter. However, neither the 14-day gain nor the 28-day gain prior to breeding date was significantly correlated with ovulation rate. Fertilization rates increased from 80.4 percent at first heat to 95 percent for third heat ($P = .08$) and 96.6 percent at fifth heat. Estimates of embryonic mortality were 24.3 percent for first heat, 31.6 percent for third heat and 6.7 percent for fifth heat. (Fifth heat data not yet complete.)

NEWS AND NOTES

The forty-fifth annual meeting of the American Society of Animal Production will be held in the Hotel Sherman in Chicago, Illinois on November 27 and 28, 1953, with a dinner for the honored guest on November 29. Abstracts of most of the papers which are to be presented at the meeting are published in this issue of the JOURNAL OF ANIMAL SCIENCE.

The nominating committee of the American Society of Animal Production composed of P. S. Shearer, E. W. Crampton and G. Bohstedt has prepared the following list of candidates to be presented at the next election of officers at the annual business meeting in Chicago on November 28.

For President: A. E. Darlow
For Vice President: J. I. Miller
For Secretary: W. M. Beeson
L. E. Harris

Alvin C. Warnick, recently at Oregon State College, joined the Department of Animal Husbandry and Nutrition at the University of Florida on October 1. He will be doing research and teaching in Animal Physiology and Reproduction.

A. L. Neumann has been named Head of the Beef Cattle Division within the Department of Animal Science of the University of Illinois, to succeed the late Professor R. R. Snapp.

George K. Davis of the Department of Animal Husbandry and Nutrition, Florida Agricultural Experiment Station, has been named as a new member of the Animal Nutrition Committee of the National Research Council.

Walter Landauer, Head of the Department of Animal Genetics at the University of Connecticut and Storrs Agricultural Experiment Station attended the Ninth International Congress of Genetics held at Bellagio, Italy, August 24–31.

Operation of the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, formerly under the Office of Indian Affairs, Department of Interior has been transferred to the Bureau of Animal Industry, Department of Agriculture. The research will be continued in cooperation with the New Mexico Agricultural Experiment Station in the aid of the Navajo Indians, but will be extended to include breeding and wool production studies for the benefit of all sheep raisers in the Southwest.

Lewis L. Madsen has returned to the Bureau of Animal Industry as head of the Beef and Dual Purpose Cattle Division, Animal and Poultry Husbandry Research Branch at Beltsville, Maryland. Prior to this assignment he served as President of Utah State Agricultural College.

W. G. Black has been appointed Assistant Professor and Assistant Physiologist at the University of Nevada. He succeeds M. T. Clegg, who has accepted a position with the Animal Husbandry Department, University of California.

B. L. Blackwell has been made Assistant Professor and Assistant Animal Husbandman at the New Mexico A. & M. College and Agricultural Experiment Station. He succeeds Ralph Durham, who resigned to engage in private poultry breeding work.

E. L. Lasley, formerly at the North Dakota Agricultural Experiment Station has joined the Animal Husbandry Department of Iowa State College, where he will be engaged in swine breeding research.

Vaughn Speer has been appointed Associate Animal Husbandman in the Animal Husbandry Department at Iowa State College.

W. B. Anthony has been appointed Associate Animal Nutritionist in the Animal Husbandry Department at the Alabama Agricultural Experiment Station, Auburn, Alabama.

T. P. Jardine is now Assistant Animal Husbandman at the Arizona Agricultural Experiment Station.

Charles E. Shelby is now geneticist at the U. S. Range and Livestock Experiment Station, Miles City, Montana.

Phillip E. Loggins, who recently completed his M.S. degree at Oklahoma A. & M., joined the Department of Animal Husbandry and Nutrition at the University of Florida on September 1.

Beginning in 1954 North Carolina State College, the University of Florida, Virginia Polytechnic Institute and the Southern Regional Education Board will jointly sponsor cooperative Graduate Summer Sessions in Statistics. The first session will be conducted by a distinguished faculty at Virginia Polytechnic Institute in the summer of 1954. Additional summer sessions are tentatively planned for North Carolina State College and the University of Florida in the two following years. Subsequent sessions will be rotated among these or other institutions throughout the South.

J. M. Boda has joined the staff of the Animal Husbandry Department, University of California.

Kent Riddle has been made Assistant Animal Husbandman at the Colorado Agricultural Experiment Station.

W. J. Nellen, Assistant Professor, is a new member of the Animal Husbandry Department, University of Delaware.

S. J. Folks, Jr., Assistant Professor and Assistant Animal Husbandman at the University of Florida, Resigned in September, 1953.

R. F. Sewell is now Assistant Professor of Animal Husbandry at the University of Georgia.

Martin Stob has joined the Animal Husbandry Staff at Purdue University, as Assistant Professor.

F. H. Baker has been appointed Instructor and Assistant Animal Husbandman at Kansas State College.

Recent additions to the Animal Industry Department, University of Kentucky, include Charles F. Buck, Assistant Professor and Assistant Animal Husbandman; Robert B. Grainger and C. M. Thompson, Assistant Professor and Assitant Animal Nutritionist.

W. E. Remple is now Assistant Professor and Assistant Animal Husbandman at the University of Minnesota.

S. H. Work of the North American staff FAO, is in Argentina conducting the nutrition phases of an International course on Pasture Management sponsored jointly by FAO, the Inter-American Institute of Agricultural Sciences, Southern Zone, and under the auspices of the government of Argentina. While there he will

consult with Argentine officials regarding plans for the Third Inter-American Conference on Animal Production to be held in Buenos Aires in late 1954.

Glen S. Bratcher has succeeded A. E. Darlow as Head of the Department of Animal Husbandry at Oklahoma A. & M. College.

J. A. Darnell, Assistant Animal Husbandman; L. C. Ulberg, Assistant Professor and R. E. Deese, Instructor, are new members of the Animal Husbandry Department at the Mississippi A. & M. College.

A Conference on Female Reproduction in Farm Animals was held at the Iowa State College, Ames, Iowa, on July 7–9, 1953. Twelve papers were presented, including summaries of the present status of our knowledge relative to the many factors influencing ovulation and the techniques of transovulation. These papers have been published as the August, 1953 number of the *Iowa State College Journal of Science*. Additional copies of this issue have been printed so that the papers of the Conference may be available to those interested in the special problems of animal breeding and may be secured by addressing the Iowa State College Press.

C. M. Chance is now Assistant Professor of Animal Husbandry at Cornell University.

V. K. Johnson has been appointed Assistant Professor and Assistant Animal Husbandman at the North Dakota Agricultural College.

Joe W. High and R. A. Reynolds have been appointed to the position of Assistant Animal Husbandman at the University of Tennessee.

R. H. Ingram has been made Assistant Professor and Animal Husbandman at the University of West Virginia.

Charles E. Poulton, Associate Professor in Range Management, has returned to Oregon State College after two years of educational leave to resume his duties in charge of the Range Management program under the Departments of Animal Husbandry and Farm Crops.

Robert B. Hallmark, formerly at the University of Connecticut, is now Extension Animal Husbandman with the University of Arkansas Agricultural Extension Service, Little Rock.

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